THE INTERNET'S SECURITY FLAW
p62

Technology Review
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Sun+ Water= Fuel

IF THIS CAN SCALE UP, WE HAVE CLEAN ENERGY
p56

PLUS

Dispatch from India: A Mobile Solution to Poverty
p48

How iJustine Became a Microcelebrity
p87

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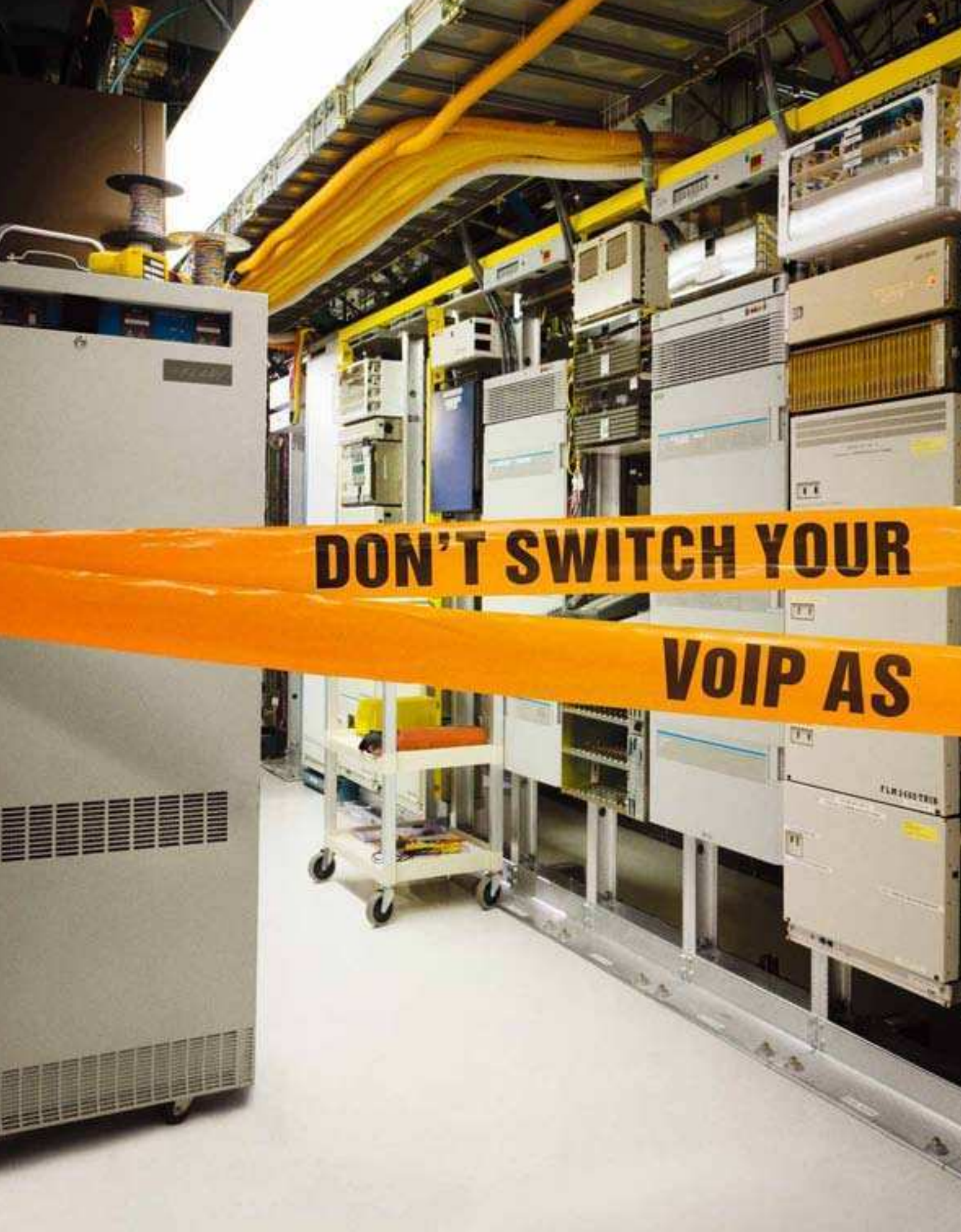
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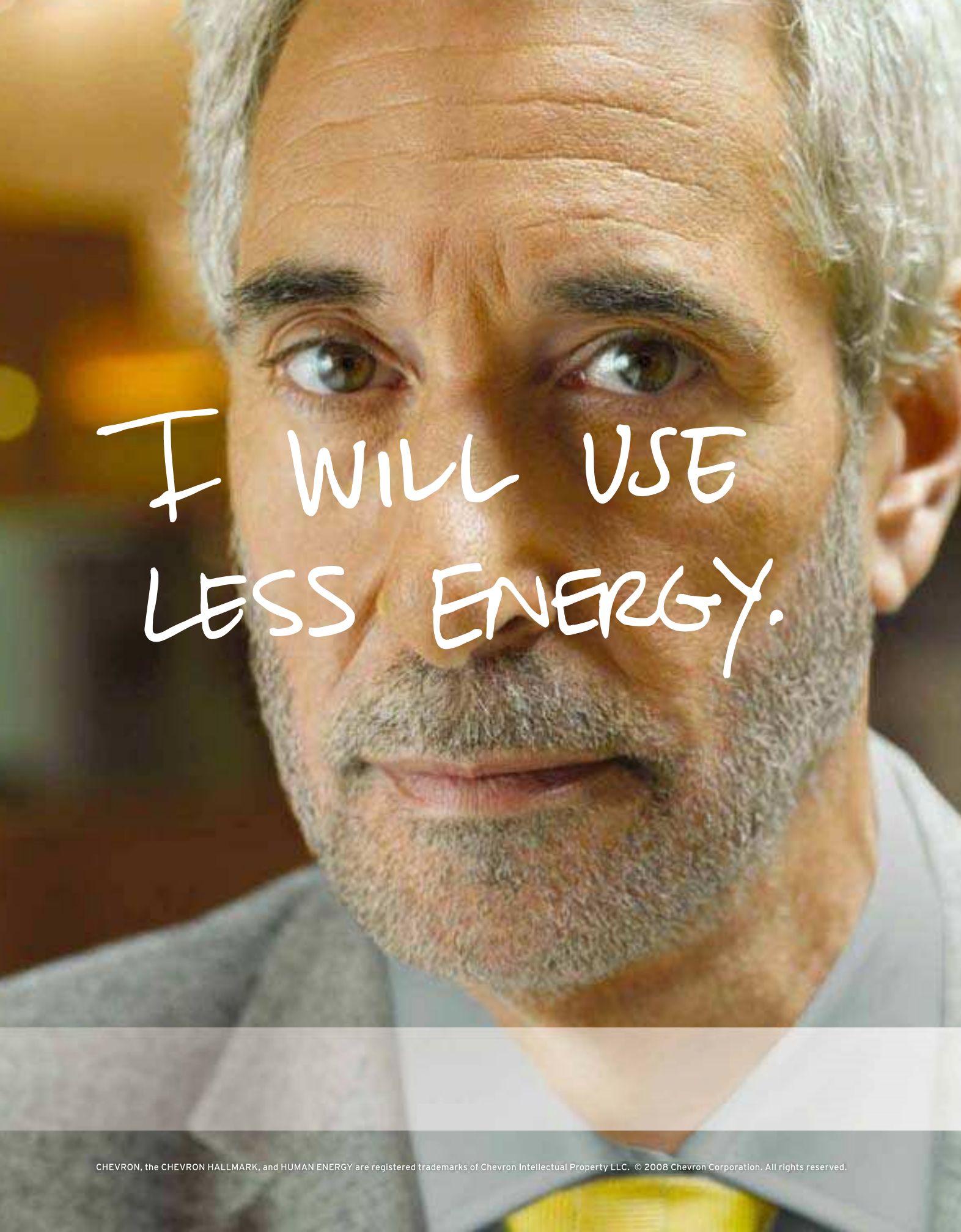

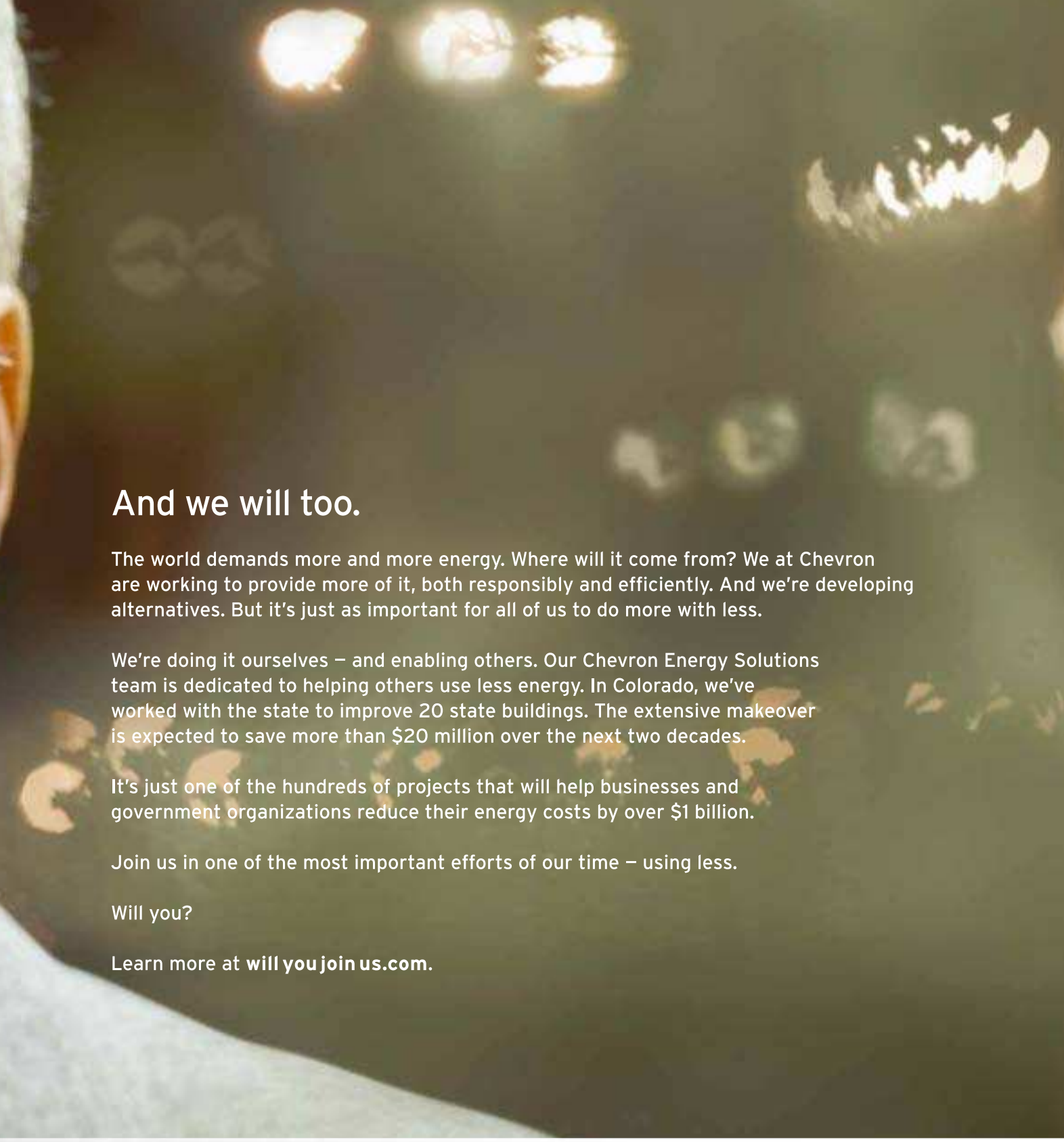

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KEVIN BULLIS, in this issue's cover story *("Sun + Water = Fuel," p. 56)*, reports on work by MIT's Daniel Nocera and others to unlock the potential of solar energy through artificial photosynthesis. "Solar power only works when the sun's out. If it's ever going to oust fossil fuels, we'll need a way to store the energy from sunlight cheaply, so we can use it after the sun sets," Bullis says. "Now chemists, by imitating the way plants store energy from the sun, may have found a way to do this, clearing the way for solar power that works day and night. The advance has ignited intense interest and controversy—making it a fascinating area to report on." Bullis is *Technology Review*'s energy editor.

GRAHAM ALLISON wrote this issue's essay on the prospect of nuclear terrorism *("Nuclear Deterrence in the Age of Nuclear Terrorism," p. 68)*. "By a combination of good sense, great fortune, and grace, we survived and protected both peace and freedom during the Cold War—without a nuclear Armageddon," says Allison. "The 21st century poses new threats that will require new thinking about unthinkables." This essay extends the argument in his 2004 book, *Nuclear Terrorism: The Ultimate Preventable*

Catastrophe, which was selected by the *New York Times* as one of the "100 most notable books of the year." Allison served as assistant secretary of defense in the first Clinton administration; he currently directs the Belfer Center for Science and International Affairs at Harvard's Kennedy School of Government, where he also teaches.

DARYL GREGORY, in his short story "Glass" *(p. 74)*, imagines a drug that can awaken empathy in those who lack it. "Psychopaths

are an interesting puzzle," says Gregory. "About 4 percent of the general population, and about 20 percent of the prison population, simply don't have a conscience. They don't feel remorse when they hurt someone, lie, or cheat. Most researchers think that the change is at the neurological level and that, quite simply, psychopaths are wired up differently from the rest of us. This raises ripe questions: what, exactly, is a conscience good for? And what would happen if you could switch it on and off?" Gregory's stories have appeared in *Asimov's Science Fiction*, *The Magazine of Fantasy and Science Fiction*, and several anthologies. His first novel, *Pandemonium*, was recently published.

MICHAEL RUBENSTEIN photographed portraits for David Talbot's feature about the Indian startup mChek, whose mobile-phone payment software could help provide banking services to the poor *("Upwardly Mobile," p. 48)*. Rubenstein, who used to live in New York, is now based in Mumbai, where he lives with his fiancée. He travels throughout South Asia photographing stories for clients; his work has appeared in many publications, including the *New York Times*, *Paris Match*, *Time*, and the *Wall Street Journal*.

POLITICAL COVER

Before even getting into my current issue of *Technology Review*, I am gravely disappointed to see an unmistakable signal of political favoritism. The cover of the September/October issue featuring Senator Barack Obama, the article on his campaign's Web strategy, and the profile of his economic advisor Austan Goolsbee combine to form a clear message: *Technology Review* is a liberal rag. I read further and now see that Obama is at "the brink of the presidency" and that he's "a new kind of presidential candidate." Posing as innocuous subheaders, these sound bites are consistent with Obama's campaign rhetoric. Such favoritism has no place in your magazine: it is inconsistent with your mission.

September/October '08

Ben Pember
Spartanburg, SC

Editor in chief Jason Pontin responds:
With great respect, *Technology Review* is neither liberal nor a rag. We are not political partisans. As for the stories to which you object, they were legitimate subjects for us: Senator Obama's campaign made novel use of emerging social technologies, and Austan Goolsbee is a technology-inspired, MIT-trained economist who made his name thinking about the Internet. Finally, whatever else the senator may be as I write these words in October, he is certainly at the brink of the presidency (he is, after all, the Democratic nominee), and he certainly is, for reasons such as his race, a new kind of candidate.

AUSTAN GOOLSBEE

I enjoyed reading Mark Williams's thoughtful portrait of Austan Goolsbee ("Obama's Geek Economist," September/October 2008), which was several cuts above typical profiles of "great" men. Austan is indeed skilled and has sensible economic priorities. The problem that any economist faces in the political arena is this: economics is fundamentally about balancing trade-offs among competing objectives (e.g., better schools vs. lower taxes), whereas U.S. political debate is largely about telling voters that there are no trade-offs. Mainstream economists believe in the virtue of free markets. Mainstream politicians appear to believe in free lunches—and their economic advisors adopt this view. Hence, the essential qualification for a presidential economic advisor should not be economic genius alone but also strength of character—a commitment to telling the president that we cannot get something for nothing. If Austan's resolve to speak truth to power is even roughly equal to his intellect, he will be an excellent advisor.

David Autor
Professor, MIT Department of Economics
Newton, MA

OBAMA'S SOCIAL NETWORK

As president of the Voter Genome Project, I was interested to read political strategist Joe Trippi's views on Barack Obama's campaign, as reported by David Talbot ("How He *Really* Did It," September/October 2008). In large part because of the technology-friendly nature of Obama's younger, better-educated supporters, his campaign used Web tools to gain an edge in fund-raising. However, we have seen little evidence that this effort pulled in voters who would not have voted for Obama otherwise. Furthermore, the focus on social-networking tools has contributed to a lack of concern for a national voter database that is failing badly.

Ron Turiello
Redwood City, CA

INNOVATOR OF THE YEAR

JB Straubel is a good pick for Innovator of the Year for his work on the electric Tesla Roadster ("The TR35," September/October 2008). Years ago, AC Propulsion wanted to hire JB, but business was down, so we couldn't. I recommended him to Tesla cofounder Martin Eberhard, and Martin had the good sense to hire him. We helped Tesla by lending it our lithium-ion-battery Tzero electric sports car and providing patents on motor and inverter designs. Tesla has since developed impressive engineering capability. After 16 years of developing electric vehicles and drive systems, AC Propulsion is doing well: we'll deliver more drive systems than Tesla this year. But JB's innovations could put Tesla ahead in 2009.

Tom Gage
President and CEO, AC Propulsion
Sunnyvale, CA

TECHNOLOGY IN THE OPERATING ROOM

Neurosurgeon Katrina Firlik's essay on the difficulty of overcoming the "fiddle factor" inherent in medical technology ("A Messy Art," July/August 2008) will be required reading at our company, a developer of intraoperative MRI systems. Out of concern for the safety of their patients, surgeons are often wary of new, unfamiliar tools and methods. For this reason, the medical-equipment industry must make sure its equipment features intuitive, easy-to-use interfaces.

Stephen G. Hushek
Milwaukee, WI

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NOTEBOOKS

Letters to the incoming president

ENERGY

Managing Power

WE NEED A PORTFOLIO OF PROVEN LOW-CARBON ENERGY TECHNOLOGIES, SAYS ERNEST MONIZ.

Dear Mr. President:

The country faces energy challenges that we cannot put off to a next administration or a next generation. We are running out of time to develop and deploy technologies that can mitigate climate risk and enhance national security.

The urgency stems from the collision of two realities. On the one hand, energy is a highly capitalized, multitrillion-dollar commodity business with highly developed supply chains, and it provides essential services and requires extensive regulation. Substantially changing the energy mix takes decades.

On the other hand, any prudent evaluation of climate-change risks suggests that concentrations of atmospheric greenhouse gases must be stabilized within a few decades. We must begin moving toward a low-carbon energy future now. Furthermore, only a global commitment will do. American leadership is essential if we are eventually to bring China and other emerging economies into a worldwide effort to mitigate these risks.

Reducing our dependence on hydrocarbon fuels will also promote energy security, providing more latitude in foreign policy.

In this context, I respectfully suggest the following actions for the first year of your administration:

(1) Implement carbon dioxide emissions pricing, most likely through a cap-and-trade system. Charging for carbon emissions will stimulate the market to introduce low-carbon technologies. The cap-and-trade system should move as quickly as possible toward an auction system, with the funds returned to the public in a progressive manner.

(2) Work with the private sector to provide a portfolio of proven, cost-effective low-carbon energy technologies. Goals should include new nuclear power plant construction, a strong renewables program, and a program to demonstrate large-scale carbon dioxide sequestration. Realistically, this will require a small charge on energy supply. The scale of the program needs to be in the range of $10 billion a year for 10 to 15 years.

(3) Establish a mechanism for coördinating the many interests that must influence a coherent energy policy: national security, foreign policy, environmental policy, agricultural policy, fiscal policy, and so on. The administration's policy position must also reflect the legitimate and often diverging energy interests of different regions of the country. The Department of Energy does not have the capacity to bring together these disparate interests without help from the White House. One option is to appoint an assistant to the president for energy, who would work with the energy secretary.

(4) Commit to implementing, within 10 years, a 21st-century electricity grid that will enable development of large-scale regional resources for renewable electricity. Introducing energy efficiency standards for new buildings and financial incentives for retrofitting existing buildings should be a high priority. TR

ERNEST J. MONIZ IS DIRECTOR OF THE MIT ENERGY INITIATIVE.

MEDICINE

Digitizing Health Care

WE NEED NEW INCENTIVES FOR ELECTRONIC RECORD KEEPING, SAYS JOHN HALAMKA.

Dear Mr. President:

As you know, the United States is spending 16 percent of our gross domestic product on health care, a percentage that is likely to rise. That might be reasonable if we were getting correspondingly high quality, but we're not. While we have some of the best individual-care facilities in the world, our system does not rank well against other industrialized nations on basic health measures.

Health-care information technology is one of the major tools the United States can use to constrain cost increases and enhance quality. To date, the U.S. has adopted electronic health records (EHRs) at a much lower rate than most other industrialized nations, including Germany, Canada, the United Kingdom, and Australia. The U.S. spends 43 cents per capita on health-care IT, compared with $193 per capita in the U.K.

Incentives to introduce EHRs and a compelling business case for continuing to use them are crucial to getting the technology adopted on a wide scale. In the outpatient setting, implementing a system of EHRs that providers can easily share costs those providers $40,000

HARRY CAMPBELL

to $60,000. Yet most of the benefits go to payers and purchasers—often the U.S. government. To fix the misalignment, the government should offer incentives directly to providers.

We need to be careful, though, about what actions the government takes. A recent Congressional Budget Office report concluded that imposing penalties for failing to adopt health IT would be more cost effective than providing financial incentives. Primary-care physicians in the U.S. are already struggling with high costs and low reimbursement. Asking them to comply with another unfunded mandate based on penalties rather than incentives won't solve the problem, because it doesn't acknowledge the underlying economic misalignment that has discouraged adoption in the first place. The result won't be more EHRs; it will be fewer medical students choosing primary-care careers, which will fuel even greater increases in health-care costs.

I recommend a three-point plan for your administration:

(1) Provide incentives through Medicare for the adoption and use of EHRs. Target these incentives so that cost savings are shared with clinicians.

(2) Encourage insurers to provide incentives for hospitals to adopt CPOE (computerized physician order entry). This technology, which lets physicians communicate treatment instructions electronically, is the most important tool hospitals can introduce to improve their safety, quality, and efficiency of care.

(3) Continue to provide federal funding for technology and policies that encourage interoperability between health-care providers.

If we coördinate the care of all Americans and ensure that every person has a lifetime electronic record, we will enjoy safer care at a reasonable price. TR

JOHN D. HALAMKA IS CHIEF INFORMATION OFFICER AT HARVARD MEDICAL SCHOOL.

RESEARCH

Reasserting Competitiveness

INVEST IN EDUCATION, RESEARCH, AND INNOVATION, SAYS CHARLES VEST.

Dear Mr. President:

Your ability to govern effectively and provide world leadership will depend profoundly on advancing and utilizing the knowledge and tools of science, engineering, and medicine.

In the 20th century, U.S. achievement in these fields protected our nation's security, fueled most of our economic growth, and nearly doubled our life span. It sent us to the moon, fed the planet, brought world events into our living rooms, established instant worldwide communications, gave rise to ubiquitous new forms of art and entertainment, uncovered the workings of our natural world, and gave us freedom of travel by air, sea, and land. It was a century of speed, power, and new horizons. We have come to take all this for granted.

The 21st century will be very different. And nothing can be taken for granted. To grasp the great opportunities of our times and to meet our challenges in a number of areas—from economic competitiveness to energy, from health care to education, from security to infrastructure—federal policy and action must be informed and enabled by a vibrant science and technology enterprise.

Indeed, our national comparative advantage is a strong science and technology base coupled with a free-market economy and a democratic society.

We will soon feel the full force of global competition. Jobs will follow innovation wherever it is found, and innovation will follow basic research. Our children must be inspired and educated for productive, well-paying jobs in this knowledge economy.

The bipartisan America Competes Act was passed and signed into law in August 2007 but has not been funded. It would jump-start improvement in K–12 science and math education, strengthen and sustain long-term basic research, make the U.S. the best place in the world to study and do research, and help ensure that we remain the most innovative nation on the planet. Its cost is about 0.14 percent of the Wall Street bailout or 1.8 percent of the annual farm subsidy.

Mr. President, the federal government must invest in our future through education, research, and innovation. I therefore believe you should take six immediate actions:

(1) Use your bully pulpit to establish a public vision of an America that will lead and prosper in the 21st century through knowledge and innovation.

(2) Appoint a science and technology advisor before your inauguration and include him or her at the highest tables of counsel and decision making, just like the national security advisor.

(3) Make full funding of the America Competes Act a nonnegotiable first-term priority.

(4) Establish a bold national initiative engaging the private sector, academia, and government to meet our energy challenge and mitigate the advance of global climate disruption.

(5) Restore strong basic-research budgets to the Department of Defense and increase the National Institutes of Health's budget in excess of inflation.

(6) Work with Congress to eliminate academic earmarking.

My colleagues in industry, academia, and government stand ready to support your new administration with fact-based advice and to provide the knowledge and innovation required for U.S. prosperity and improved life around the world. TR

CHARLES M. VEST IS PRESIDENT EMERITUS OF MIT AND PRESIDENT OF THE NATIONAL ACADEMY OF ENGINEERING.

Dear Mr. President

Like snowflakes upon a sea, and as little regarded, are letters to a new president.

Frustrated former presidents, fretfully retired statesmen, and senators ambitious to sit in your cabinet want you to enjoy their wisdom. Ordinary citizens take to their keyboards, as befits a democracy. Captains of industry, those proud alumni of the Polytechnic of Life, are determined to level with you. Even intellectuals—scientists, economists, and, Someone forgive us, magazine editors—feel the solemn duty to buttonhole you about what you must do in the first months of your administration.

Wired magazine devoted its October issue to "a Smart List of 15 Wired people with big ideas about how to fix the things that need fixing." More selectively, we have asked three *éminences* of science and technology to advise you. (Letters from Ernest Moniz, the director of the MIT Energy Initiative; John Halamka, the chief information officer of Harvard Medical School; and Charles Vest, MIT president emeritus, appear on pages 10 and 11.) All try to make action urgent and its nature clear.

As will I. Whoever you are, you will have pressing demands upon your attention. As I write in mid-October, a burst financial bubble appears to be leading to a global crisis of liquidity. You must fight two protracted wars. The very weather frightens. And at home and abroad there is a general malaise about the American project: to many, the United States, which Ronald Reagan, echoing Lincoln, often called "the last, best hope of man on earth," seems to have become one of the ordinary nations.

The promotion of science and technology must feel very far from your priorities. But encouraging America's scientists and technologists is essential to the well-being of your fellow citizens and (insofar as the United States has been the world's wellspring of research and development) of everyone alive.

It was so before. In the 20th century, U.S. achievement in science, engineering, and medicine "protected our nation's security, fueled most of our economic growth, and nearly doubled our life span," Chuck Vest writes. "It sent us to the moon, fed the planet, brought world events into our living rooms, established instant worldwide communications, gave rise to ubiquitous new forms of art and entertainment, uncovered the workings of our natural world, and gave us freedom of travel by air, sea, and land."

Science and technology may astonish the 21st century, and they can help solve many of the problems you face; but they will flourish only if the federal government funds long-term discovery research. Venture capitalists and entrepreneurs will develop the most commercial discoveries; but the discoveries are the fruit of research for which there is no sure application.

Your predecessor hardly cared for such stuff. Over the last eight years, most federal funding of research was reduced or maintained at the same level (and therefore declined after inflation). Only one area of research really prospered: science and technology with applications in security and defense. Generally, U.S science and technology is suffering.

Consider, for example, research into alternative energy. In testimony before the House Select Committee on Energy Independence and Global Warming in September, MIT's president, Susan Hockfield, told legislators that in 1980, 10 percent of federal research dollars went to energy. In 2006, she said, it was less than 3 percent: between $2.4 and $3.4 billion, or less than half the annual R&D budget of the largest North American pharmaceutical company. Hockfield called for Congress to begin by tripling funding for energy research.

You should champion such increases. In the cover story of this issue *(see "Sun + Water = Fuel," p. 56)*, Kevin Bullis shows why. He describes a catalyst developed by Daniel Nocera, a professor of chemistry at MIT, that generates oxygen from water, much as plants do during photosynthesis. Bullis writes, "The reaction is the first and most difficult step in splitting water to make hydrogen gas. And that advance, Nocera believes, will help surmount one of the main obstacles preventing solar power from becoming a dominant source of electricity: there's no cost-effective way to store the energy collected by solar panels."

This is a tremendous advance: if artificial photosynthesis works at a larger scale, we have clean power. Nocera's current research is part of a $21.5 million program, funded by the National Science Foundation, that will continue until August 2013. But Nocera has been working on artificial photosynthesis since the early 1980s, and it will take another decade to commercialize his work. If we judge by recent emerging energy technologies, that commercialization will demand hundreds of millions of dollars more. Until venture capitalists have been convinced of the technology's promise (and potentially for longer, if the financial markets cannot offer an exit strategy to justify VCs' investment), much of that money must come from the federal government.

Mr. President, please work with Congress to increase research funding. Science and technology can expand human possibilities, but only when they are themselves expansive.

—Jason Pontin

MARK OSTOW

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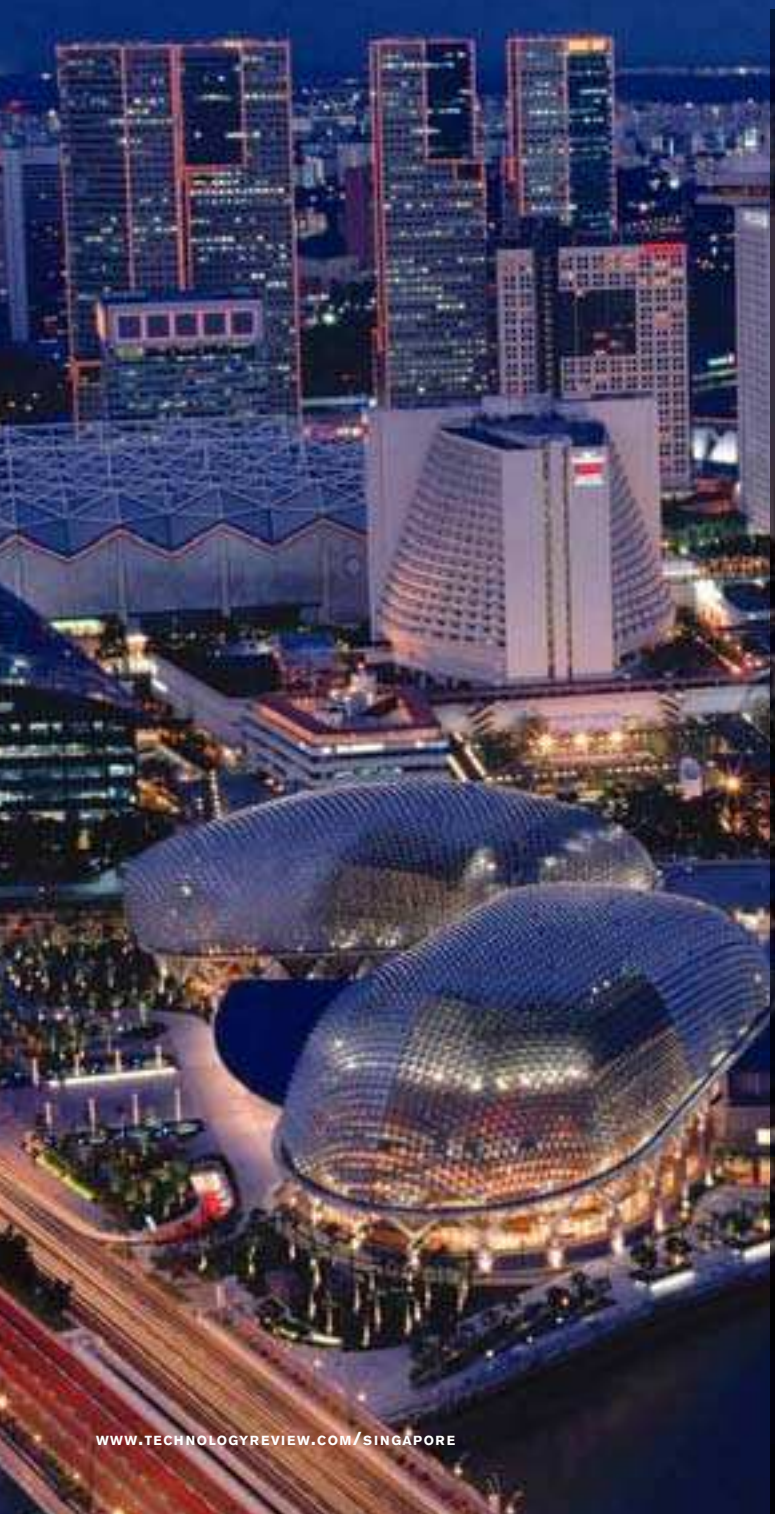


A lion, clad in gold and scarlet, slumbers by the new buildings. To awaken the creature, Singapore Prime Minister Lee Hsien Loong touches its image on a screen. Its eyelids flicker and open. The beast pulls itself up and bows and dips in a rhythmic traditional dance, which has augured good luck through thousands of years of Chinese history. Nearby, the looming towers collectively called Fusionopolis are officially declared open.

The robotic lion, created by the national laboratories of the Agency for Science, Technology and Research (A*STAR), Singapore's lead research agency, represents the local spirit of innovation and heralds the opening of the country's latest and most striking addition to its growing science complex.

Fusionopolis brings together national laboratories, corporate laboratories, and emerging businesses. It builds on the country's success with Biopolis, which opened in 2003 and focuses on the life sciences. The two centers, part of a dynamic development called one-north, exemplify Singapore's aspiration to claim its place as an international center for research, technology, and innovation.

A former British trading post, the country has been dubbed an economic miracle by many, because it has achieved an average of 8 percent growth per year since gaining independence in 1965. This growth was anchored by its success in attracting foreign investment, which helped the country build up a strong manufacturing base. But government officials realized Singapore could lose its edge to nearby countries if the economic winds were to shift.

As a result, officials surveyed other countries with populations not much larger than Singapore's. "Other small, successful economies like Switzerland, Finland, and Sweden's invariably have a high investment in research and development," says Lim Chuan Poh, chairman of A*STAR. "These economies have invested 3 percent or more [of GDP]."

Setting a similar target, the government dedicated about S$6 billion from 2000–2005. That amount was doubled to S$13.5 billion for 2006–2010.

Singapore launched its well-known life sciences initiative in 2000. The government focused on attracting top life sciences talent to the country and set up 13 research institutes and consortia under A*STAR.

Biopolis followed in 2003. The idea behind that development was to bring the life sciences institutes together and to invite pharmaceutical corporations, courted by the Singapore Economic Development Board (EDB), to set up local laboratories.

"It might seem like the obvious thing to do today. But back then, the divide was very clear. In the U.S., I think it's difficult to imagine having [private] companies located next to the National Institutes of Health. So this was really novel," says Beh Swan Gin, managing director of EDB.

Today, Biopolis hosts two thousand researchers, and R&D labs of major international corporations such as GlaxoSmithKline, Novartis, Eli Lilly and Takeda. In economic terms the experiment was a success as well: from 2000 through 2007, the share of the national economy contributed by the biomedical sciences quadrupled from S$6.3 billion to S$24 billion.

Government agencies have now set their sights on addressing global megatrends, such as rapid urbanization, climate change, and an aging population, to grow Singapore's economy. These societal trends require unique solutions and approaches, and Singapore wants to be the place from which such innovations are developed.

The country has a head start, because in the last 15 years it has invested in seven science and engineering research institutes to support its existing manufacturing clusters. These institutes have distinguished themselves in their fields, nurturing a talent pool of 1,300 researchers with diverse expertise in materials science, microelectronics, chemical synthesis, information and communications, data storage, high performance computing, and manufacturing technologies.

The only way we're going to create products and services that tackle large and complex societal problems is by bringing together experts who have deep knowledge in particular areas.

But a new approach is now required, says Charles Zukoski, chairman of A*STAR's Science and Engineering Research Council, which oversees the seven institutions.

"The only way we're going to create products and services that tackle these large and complicated societal problems is by bringing together experts that have deep knowledge in particular areas. This means creating an environment where multidisciplinary teams can flourish, while sustaining deep domain expertise," adds Zukoski.

Fusionopolis embodies this new cultural change. Beginning in 2008, A*STAR is bringing six of these research institutes under a single roof at Fusionopolis to engage in multidisciplinary research aimed at tackling complex global challenges. The researchers will be working with another thousand A*STAR life sciences researchers at Biopolis, just half a mile away.

Fourteen corporate laboratories are moving into Fusionopolis, adding diversity and potentially reducing the time to market of new technologies.

Vestas is one of the international corporations that has moved into Fusionopolis. The world's leading wind turbine company decided to make Singapore its first Asian R&D center. Matthew Low, vice president of Vestas Technology R&D, explains that Singapore's location in and access to Asia, the science and engineering talent at Fusionopolis, and the local infrastructure all played roles in the choice of Singapore over other possibilities. Although Singapore lacks wind, he says, "we can tap into electronics, materi-

Fusion of ideas

On October 17, 2008, Fusionopolis officially opened its glass doors to the public.

The opening marks the first step of a 30-hectare experiment to bring diverse ideas, talent, expertise and businesses together in one compact environment to create new innovations.

It houses 800 scientists, engineers and game developers from laboratories of A*STAR and corporations in the infocomm technology, media, physical sciences and engineering industries. By 2012, that number will reach 2,400.

"As the master developer, usually you'd be more interested in how many acres you develop, how many new buildings you build," says Philip Su, assistant chief executive officer of JTC Corporation. The nation's leading provider of industrial space solutions, JTC Corporation was appointed the master-developer and planner for the 200-hectare one-north that encompasses Biopolis and Fusionopolis.

"We said, no, that's not what we are looking at. What is important is how many national and corporate labs there are, how many patents are created through collaborations, and which strategic companies are attracted to Singapore. Because it is in the labs that you get breakthrough ideas and develop intellectual property."

Companies such as Ubisoft, EA, Linden Labs, Asian Food Channel, Panasonic, and Vestas are among the 14 corporations that have set up laboratories and workspaces in Fusionopolis. Construction continues at a rapid pace to meet the strong interest of additional companies.

Government agencies tasked to grow the economy, such as EDB, MDA, and SPRING Singapore, will also have offices at Fusionopolis.

The success of Fusionopolis rests on how well it helps to foster connections.

Designed as an iconic development by the late internationally renowned Japanese architect Kisho Kurokawa, it offers an integrated "work-live-play-learn" environment to foster that chance encounter that could spark the next big discovery.

On the top three floors of one of the towers is Singapore's largest gym, which features a rooftop pool with a panoramic view of the island. Another tower hosts a 50-unit full-service apartment development made up of work lofts that comprise the "live" component.

Cafes, pubs, restaurants, retail outlets, and a Cold Storage supermarket are located throughout the development, which by 2011will also be serviced by a subway. These lifestyle areas double up as testbedding sites.

A 480-seat "black box" theater rests on a single column at Fusionopolis. Offering unique acoustic elements, it can be configured for conferences, exhibitions, or the performing arts.

The building incorporates the latest in eco-sustainability. It features a unique double-skin structure that cools the building by blocking solar radiation with glass curtain walls, reducing air-conditioning costs by 30–35 percent. Electronic ballasts are installed in all fluorescent lighting fixtures, which offer 35–65 percent energy savings. A drip-irrigation system and rain sensors help to minimize water consumption. Thirteen sky gardens act as green lungs to diffuse heat and save energy costs, while dou-

als science, and structural and mechanical engineering, which are all directly relevant to wind turbines."

Other companies located at Fusionopolis include Ubisoft, Europe's largest game development company; Linden Labs, the creator of Second Life; and media companies like Asian Food Channel. Their presence reinforces Singapore's long-term vision to grow R&D in the interactive digital media sector, while creating opportunities for traditional media to develop new business models, content, tools, and services to keep pace with accelerating digitization.

The spirit of innovation reaches all the way to Singapore's small and medium-sized enterprises sector. In May this year, local company Nanyang Optical unveiled the world's first eyewear frame made from almost 100 percent recycled materials, developed in partnership with A*STAR. SPRING Singapore, a government agency, partners with these local enterprises, provides them with funding and advice and links them up with local research organisations. More than 400 such enterprises have been supported.

"The end objective is to generate and nurture more technologically innovative and highly scalable startups for Singapore, similar to those found in technology hotbeds like Silicon Valley, Boston, and Taiwan," says Png Cheong Boon, SPRING's chief executive.

More research activities can be expected as the one-north community grows. JTC Corporation, the master developer and planner for the 200-hectare one-north development that encompasses Fusionopolis and Biopolis, is adding residential units, commercial hubs, hotels, and green spaces to attract more research institutions and private companies. The aim is to create an integrated "work-live-play-learn" environment where talent can connect with one another easily.

All these broad-reaching projects and initiatives comprise a "whole-of-Singapore" approach, officials say, to foster a spirit of innovation and propel the country's intellectual and economic growth.

Says Lim Chuan Poh, "Our aim is to achieve at least the research intensity of San Diego and, in the longer-range future, to near that of Boston. When people think of doing research, they may think Boston, places in California, Cambridge, Oxford or London. We want Singapore to be a place they consider as well. Then we would have created a world-class international research hub."

LAND SIZE: 682 KM²

POPULATION: 4.8 MILLION

OFFICIAL LANGUAGES:
ENGLISH, MALAY, CHINESE, TAMIL

GDP (2007): S$229B
(7.7% GDP GROWTH)

R&D EXPENDITURE (2007): S$6.3B
(2.61% OF GDP)

R&D WORKFORCE (2007): 27,300

*The robotic lion, created by A*STAR researchers, represents the local spirit of innovation and heralds the opening of Singapore's Fusionopolis.*

bling as ideal social spaces.

The overriding idea behind these innovations is to create beautiful communal areas that facilitate the flow of ideas. Adds Su, "We do not just focus on providing the best real estate solutions or the most reliable infrastructure. Rather, we want to cultivate a dynamic community, where people are interacting and connecting, and to spark ideas."

By providing an integrated ecosystem and promoting cross-disciplinary research and collaborations among national and corporate labs, Fusionopolis will act as a catalyst for dynamic public-private partnerships, fostering innovation and experimentation in a vibrant learning environment.

one-north: *Fusionopolis is part of a larger development called one-north, which is the icon of Singapore's knowledge economy.*

The 200-hectare development is being built in phases over 15 to 20 years to be a focal point for R&D and technopreneurial activities in Singapore. It redefines the way space is used to meet the needs of next generation businesses and talent that value interactions within a "work-live-play-learn" setting.

Singapore: a living lab

The idea of Future•Singapore is simple. The world is undergoing dramatic social and demographic changes–such as urbanization and climate change–and companies are searching for commercially-viable innovations to address these issues.

There needs to be a place to hatch new ideas and test concepts, and Singapore provides a conducive environment as a living laboratory where companies can experiment and develop world-class solutions. These are solutions which Singapore needs, and these products and services can then be exported to global markets.

"We believe that given our research community, between the Singapore-based companies and the government, we can be very good partners for international companies to co-create these solutions and businesses. This is how Singapore adds value to the process," said Beh Swan Gin, managing director of EDB.

"Take water as an example. We wish to be self-sufficient, and so we went about looking at the kind of water technologies we can develop, be it in desalination or recycling. Over the past few years we have enjoyed tremendous success. Now both foreign and local companies are using technologies that were test-bedded and developed here, and selling them all over the world," adds Beh.

Singapore's close proximity to a rapidly expanding Asian market, including economic giants China and India, also means that companies are close to the markets they want to serve.

Singapore provides a conducive environment to hatch ideas, test solutions and export them to global markets.

The critical factor in developing Singapore as a living laboratory is its science and technological base. A big draw for companies is the ready access to talented researchers. The research workforce increased from 15,800 in 2000 to 27,300 in 2007. "This is also an opportunity to position Singapore as an attractive location for talent from all over the world," said Beh, citing Singapore's cosmopolitan and safe environment as qualities that have attracted global talent to its shores.

The move to extend the breadth and depth of Singapore's multi-disciplinary science and technology capabilities has helped the country to anchor more capital, knowledge, and innovation-intensive activities.

For example, Renewable Energy Corporation ASA is setting up its new global-scale integrated solar-manufacturing complex in Singapore. When fully operational, the complex is expected to produce up to 1.5 gigawatts (GW) of solar products. In comparison, the total worldwide output for such products amounted to about 2.5 GW in 2006. The investment is a boost to Singapore's up-and-coming clean energy industry.

More corporate labs headed to Singapore

About 380 international corporations were engaged in R&D activities in Singapore in 2007, a 70 percent increase from just 220 international corporations in 2000, according to Singapore's national R&D survey.

Most of these were U.S., European and Japanese companies.

Biopolis and Fusionopolis have been important in attracting these corporate R&D labs.

"Companies enjoy the ability to avoid heavy upfront capital investment in scientific infrastructure and to recruit scientists easily, because the [right] post-doc may be working at a lab next door," says Beh Swan Gin, managing director of EDB. "At lunch [researchers] can attend seminars and scientific talks."

Alex Matter, director of the Novartis Institute for Tropical Diseases, located at Biopolis, says that many factors encouraged Novartis to settle in Singapore: a shared common language, its location in the center of East Asia, good schools for the children of its employees, a high level of safety in the streets at all hours, and first-class technological and scientific facilities.

Singapore was also the site that EADS chose when it decided to open its first Research and Technology (R&T) Center outside of Europe.

The company has significant collaborations with A*STAR, and is a founding member of A*STAR's aerospace R&D program that brings together three other aerospace giants–Boeing, Pratt & Whitney and Rolls-Royce–in pre-competitive research. Under this program, companies and A*STAR researchers work together on projects that might be seen as too high risk to undertake alone.

Says Ulrich Schnaut, chief operating officer of the EADS Singapore office, "Singapore has a vibrant world-class research community. There is a thriving maintenance, repair and overhaul business, a strong IP regime and a supportive pro-industry, pro-research government. All these are factors which attracted us to Singapore."

Building bridges in science

Universities around the world are bringing their faculty and departments together in multidisciplinary research to crack large societal challenges confronting the globe.

Singapore is moving ahead to foster such close collaborations with the opening of Fusionopolis, which is dedicated to science and engineering research.

"We are well ahead in this experiment," says Charles Zukoski, chairman of A*STAR Science and Engineering Research Council (SERC). Three of the research institutes under his charge have moved into Fusionopolis: the Institute for Infocomm Research (I^2R), the Institute of High Performance Computing (IHPC), and the network storage lab of the Data Storage Institute (DSI).

The rest will move in by 2011. These are the Institute of Materials Research and Engineering (IMRE), the Institute of Microelectronics (IME), the Singapore Institute of Manufacturing Technology (SIMTech), and the remaining labs of DSI. The seventh institute, the Institute of Chemical and Engineering Sciences, will remain at Jurong Island, which is just 30 minutes away from Fusionopolis.

This physical move gives Zukoski and SERC's executive director, Chong Tow Chong, the opportunity to transform the research institutes and to regroup them into core and multidisciplinary labs.

Referring to the growing challenge of an aging population, Zukoski says, "If you want to keep your mother at home before she goes to a nursing home, what does that mean? You might need ways of communicating with the doctor, of getting food delivered or cooked differently, maybe health monitoring. Designing that requires data storage, microelectronics, communication and more. You need a multidisciplinary team."

"This thrilling experiment is made possible because we are starting off from a very high science and technology base built in the last 10 to15 years," says Zukoski of the 1,300 research scientists and engineers in the seven research institutes he leads.

The achievements by his institutes include I^2R's Advanced Audio Zip (AAZ), an alternative to MP3 technology that has been accepted as an ISO standard—a first for Singapore. Unlike MP3 compressed files which tend to lose the richness of music recordings that use a wide signal range, AAZ allows for files to be stored in compact form and go back to be as crystal clear as the original.

Another feat is the ultra-low flying femto slider for extremely high density magnetic data storage. The technology won DSI the Information Storage Industry Consortium Technical Achievement Award—the first institution outside the United States to win this award.

We want the barriers to fall down and synergies to gush up.

"We have a solid track record. With the range of expertise we have, it is possible to do experimental, theoretical and computational projects all under one roof. It makes the pursuit of science more exciting," says Chong.

Lim Chuan Poh, A*STAR chairman, wants to take this multidisciplinary approach to cover the life sciences and physical sciences and engineering.

Standing by the glass wall of a meeting room on the 21st floor of Fusionopolis, he gestures toward a group of buildings half a mile away that hosts A*STAR's 13 biomedical research institutes and consortia. "That's Biopolis."

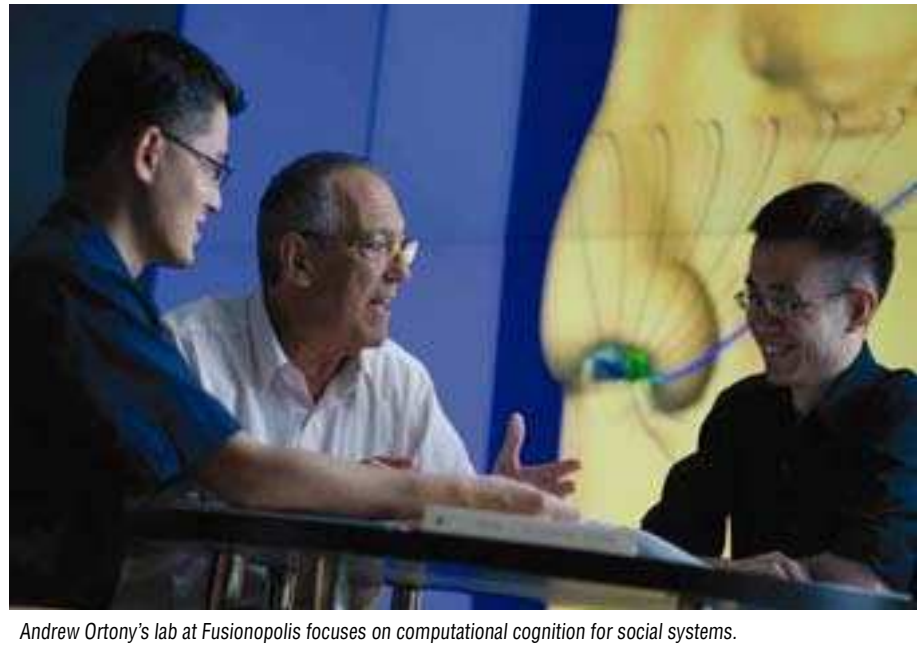
He is maximizing this rare proximity between the life sciences and physical sciences and engineering by setting up the A*STAR Cross Council Office to encourage collaborations.

"Many new breakthroughs are being developed at the edges of different disciplines. We have a critical mass of researchers at Biopolis and Fusionopolis. We want the barriers to fall down and synergies to gush up," he says.

A*STAR scientists have been enthusiastic about collaborating, even before their official move to Fusionopolis and the setting up of the Cross Council Office.

Since 2007, eighty researchers have come together to work on technologies for homes of the future.

Also in the making is an ingestible capsule



Andrew Ortony's lab at Fusionopolis focuses on computational cognition for social systems.

developed by a 30-member multidisciplinary team that will incorporate therapeutic functions. It will be able to collect tissue samples for biopsy or perform targeted drug delivery, in addition to sending video footage wirelessly to doctors for immediate diagnosis.

This focus on multidisciplinary research is attracting scientists who are interested in pursuing science at the intersection of fields.

Andrew Ortony, a cognitive scientist and professor at Northwestern University, is opening a lab in Fusionopolis as an A*STAR visiting investigator. His group will explore the complex dynamics of social interaction in humans and build computational models of these processes that can be used in artificial systems. He expects his team's research to contribute to the next generation of work in social robotics. "Robots of the future will have to be able to interact with humans in sensitive and socially appropriate ways—for example, in the context of elderly care," he says.

Ortony is in the midst of assembling an interdisciplinary team of researchers with backgrounds in areas such as social and cognitive psychology, computational linguistics, decision theory, cognitive architectures and multi-agent systems, and social robotics.

"It has been an amazing experience. Not only is the research group highly interdisciplinary, it is also highly international. We now have fifteen research staff and affiliates from eight different nationalities," he adds.

Both Lim and Zukoski agree that it all boils down to building a culture of collaboration.

The "work-live-play-learn" environment at Fusionopolis and Biopolis, with cafes, pubs and restaurants, aims to create spontaneous interactions.

Scientific facilities are also shared. "Researchers spend most of their times in labs. These shared facilities create more opportunities for the scientists to speak to one another," says Chong.

"Singaporeans are well-known for our ability to work together—it's ingrained in our DNA," says Lim. "We're trying to infuse this into the research culture in Singapore."

Innovations that *dazzle*

A new ecosystem of innovation is building up in Singapore, with startups, local companies and national laboratories creating new, dazzling technologies and innovations.

Interactive digital media

University students created two of Singapore's successful start-up companies by entering the fray of gaming and virtual worlds.

Fresbo began when several friends decided it would be entertaining to create their own virtual world. They developed technology to manage tens of thousands of users and created worlds that would be particularly appealing to an Asian market, with avatars that resemble anime figures.

What this company did that was different, however, was to create a world that bridged social networking sites. "We wanted people from Friendster or Facebook to communicate with each other. This is something very different from other virtual worlds," says Low Bingjiang, CEO and a Fresbo founder.

Users who add the game application to their sites can begin playing immediately. This feature has also allowed Fresbo to market itself through the user sites, offering, for instance, free furniture to decorate online homes if users invite friends to join. After only four months, Fresbo became the top game in Friendster, with about 300,000 players.

Seed money and mentoring from the multi-agency Interactive Digital Media R&D Programme Office (IDM PO), hosted within the Media Development Authority of Singapore (MDA), helped Fresbo to get started, just as it assisted the founders of gaming company Garena.

Garena developed a solution that tapped into two global forces: gaming and global interconnectivity.

"We are all gamers," says Dinesh Raju, one of Garena's young executives. "We thought it'd be great to play games within a global community. So we wrote an application that allows people to play LAN (local area network) games over the Internet."

Making use of unique network-shaping technology, Garena created software that turns the Internet into a cyber café connecting gamers worldwide. Its technology offers a faster, fairer and more entertaining way to wage online battles.

"You can choose your opponents from a much wider variety of people, many in other countries. You get to see how other people play these games and improve your skill," adds Raju.

In the year and a half since releasing the first version of the software, Garena attracted seven million registered users from 180 countries, with close to 200,000 logged on at peak times.

It's a boost not only to gamers, but also game

Using unique network-shaping technology, Garena created software that connects gamers worldwide.

developers. The latter can now focus on creating compelling games, while taping on Garena's innovation for multiplayer games.

The Singapore government is dedicating about S$500 million over the next five years to encourage the growth of interactive and digital media. "This will help Singapore achieve our vision of becoming a global media city," says Tan Chin Nam, chairman of MDA.

Since the setup of the IDM PO Office two years ago to oversee R&D initiatives and develop a complete ecosystem to grow the sector, significant headway has been achieved. Milestones include local media companies embracing new media as with SPH's Razor TV. Early-stage funding is also provided to encourage innovation by startups. Some have attracted private investor funding to take their ideas to the next stage.

Last year, 94 projects were supported, which will deliver some 100 patents and new services.

One key focus is to develop pedagogical breakthroughs based on IDM-based teaching approaches, tools, and media. The hope is that all schools in Singapore will be able to embrace IDM for more effective teaching and learning. Six local schools have been designated as FutureSchools for pilot projects.

The IDM PO Office also aims to attract renowned international institutes to partner with local universities. For instance, MIT has set up GAMBIT GameLab in Singapore to conduct research addressing the challenges faced by the global digital game research industry. The National University of Singapore (NUS) has partnered with Japan's Keio University to explore the use of media in nontraditional settings, such as an umbrella that tracks its user's location.

Mozat, a company spun off from the National University of Singapore, aims to link the developing world to the Internet through mobile phone technology. "For a lot of people, their first experience on the Internet is not on a PC, it's on the mobile phone," says Michael Yin, Mozat's CEO.

The browsers on many mobile phones are limited, however, and often the price of the Internet-friendly phones places them out of reach of Mozat's chosen market. The challenge in creating a single navigation method that works across all sorts of phones is that there are many different platforms.

So Mozat creates a base on which different applications can be built. Yin hooks the phone to a screen and pulls up the application. He easily runs through e-mail, toggles between Chinese and English, and pulls up a web page. The technologies developed fit a mobile phone's speed and screen size. Information is stored not on the phone, but on a server.

Mozat's goal is to license the technology to phone carriers. "Imagine a little boy, isolated on an Indonesian island: he deserves to have the same opportunities as boys in the United States who access the Internet on a PC," says Yin. "We want to mobilize the future."

Commenting on IDM PO, Tan says, "We're confident that this program will generate many exciting products and services. It will certainly help position Singapore as a preferred location for breakthrough R&D in IDM."

Life sciences, health and wellness

In 2000, Singapore launched its biomedical science initiative to build basic research capabilities and attract multinational corporations. Top scientists were brought in to set up biomedical research institutes. Biopolis was set up in 2003 to be the headquarters for both these institutes and the corporate labs.

Today, the country is moving into its next phase, as a center for translational and clinical research.

"There's the opportunity to study diseases here that are common in Asian populations [such as certain types of cancer] but not as common in the West, and therefore not well studied by researchers in Europe and North America," says Andre Wan, deputy executive director of A*STAR Biomedical Research Council.

Since 2006, A*STAR has been working closely with the Ministry of Health and local hospitals to create the network to support "bench-to-bedside" research. S$1.5 billion has been set aside over five years to develop the infrastructure and research programs.

Lab-on-chip by Veredus and STMicroelectronics

Certain diseases and branches of medicine have been identified as high-priority: cancer, cardiovascular and metabolic disorders, neurosciences, infectious diseases and ophthalmology. Work in gastric cancer, glaucoma and severe psychotic disorders has already begun.

Singapore hosted its first "first-in-man" clinical trial in 2006, when health-care company Abbott tested a small-molecule drug for treating advanced stages of lung cancer—a coup for the country, as the traditional centers for early-phase clinical trials are in US and Europe. The success of the trials has led Abbott to select Singapore as one of the locations for the drug's phase 2 clinical trials.

Research from A*STAR biomedical research institutes is also feeding into the local biotech industry. Veredus is one such success. Founder Rosemary Tan licensed a technique for malaria detection from the Institute of Molecular and Cell Biology. Together with the Genome Institute of Singapore, they developed a testing kit for avian influenza that was released commercially in 2005. The World Health Organization deemed the kit the most accurate and reliable available, and the US Navy acquired it for onboard flu testing facilities. More recently, the company collaborated with STMicroelectronics, a European semiconductor company, to develop VereFlu, a lab-on-a-chip designed to detect and identify all subtypes of human influenza. The chip was released commercially in 2008.

New local innovations in medical technology are also contributing to the country's growing biomedical manufacturing sector. SPRING Singapore has channeled assistance to help local companies seize these new opportunities.

Artificial kidney vest from AWAK Technologies mimics the functions of a normal kidney. It performs continuous dialysis, so the patient can go anywhere with it. The cartridge that cleans the toxins from the kidney fluid lasts eight hours before it needs to be changed.

Neo Kok Beng, CEO of AWAK Technologies, hoists a lightweight vest over his shoulders and arranges it evenly. Two plastic lobes embedded in the front of the vest rest at his stomach. They house a tangle of tubes, wires, and filters that perform the duties of external artificial kidneys.

Typically, kidney failure leads to dialysis, a thrice-weekly hospital-based process that may take almost a full day. This can prevent patients from carrying out a normal work-load or traveling.

Current research alternatives focus on home-based dialysis, but these still leave patients tethered to an immobile machine.

"This machine mimics the functions of a normal kidney," says Neo. "It performs continuous dialysis, so the patient can go anywhere with it." He points out that the vest need not be worn at all times; a patient may rest it next to a desk or by the bedside. The liter of fluid that the machine uses is recycled and regenerated. The cartridge that cleans the toxins from the kidney fluid lasts eight hours before it needs to be changed. The machine is currently in the testing and development phase.

Ting Choon Meng, founder and executive director of HealthSTATS International, believes his innovative solution will have a significant international impact.

Today, hypertension is diagnosed by a brief test in a doctor's office. "This is far from ideal," says Ting.

"Studies have shown the superiority of a 24-hour blood pressure pattern in predicting a stroke [or] a heart attack, and whether you will die from that attack," he explains.

24-hour monitoring already exists, but it is bulky, with a pump that activates every half hour to tighten its grip, which disrupts a patient's sleep.

Instead, Ting has developed a BPro "watch" that rests lightly on the wrist's pulse point and captures the arterial pulse wave. The watch's sensor converts the pulse waveform into blood pressure and heart rate over 24 hours. It also measures the arterial waveform to provide information on the stiffness of the artery, because stiff arteries can lead to heart failure and stroke.

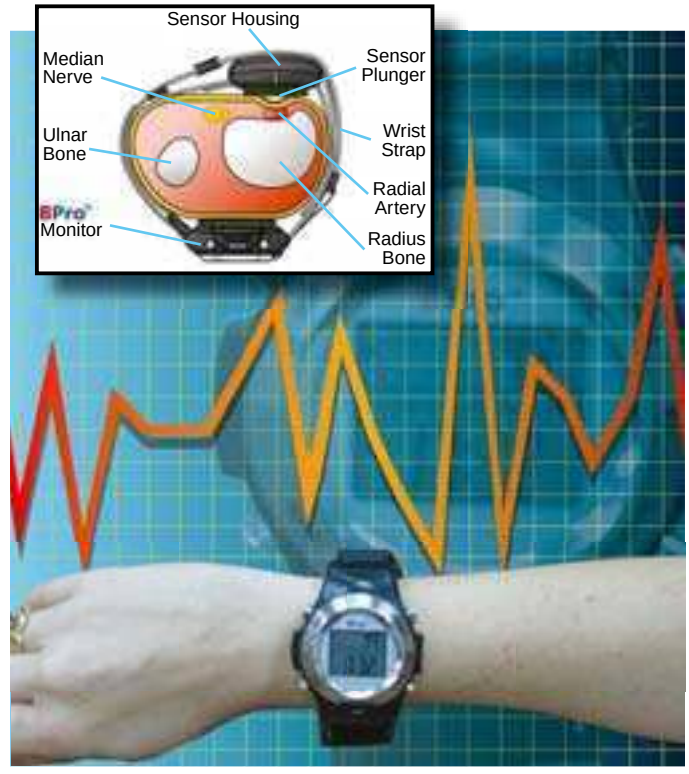
After 24 hours, the information from the BPro watch can be uploaded to a computer. The occasions when the patient's blood pressure and heart rate dips or spikes can be identified, and his overall risk moderated by the specific timing and dosage of drugs. The watch's software and the mathematical formula for interpreting its output have been tested on thousands of patients, and have been patented and received FDA approval.

Guan Cuntai from A*STAR Institute for Infocomm Research (I^2R), is working with local hospitals to "read the minds" of stroke patients.

One result of a stroke is paralysis, which is caused by the death of neurons that command muscle movement. Fortunately, the brain's plasticity is known to allow neurons in other sections to take over control from damaged areas.

Guan hopes to speed up the process of reconnecting the motor intent to the desired activity, using his team's brain-computer interface technology.

The technology is non-invasive. Patients are given a specific task, for instance to play a computer game. They wear a cap covered with electrodes that is connected to a computer. When they fire, neurons release electrical impulses that computers understand and connect to the patients' desired movements. The team develops the algorithms that help to determine the patients' intentions. The same technique is also being applied to help children with attention deficit hyperactivity disorder to concentrate better.



The BPro "watch" from HealthSTATS International measures blood pressure and heart rate over 24 hours. The diagram (insert) shows the cross section of the wrist with the BPro monitor and sensor.

Lifestyle and urban solutions

Hui Siew Kok, the head of local enterprise BITWave, made his name in audio engineering and designed products for the government defence forces. The same technology, he realized, could be applied in an increasingly connected and noisy world, where communication is constant even as external sounds compete for attention.

The company is tapping on the lucrative eldercare market by developing an audio-based system that can track the movements of the elderly in their homes, with support from SPRING Singapore.

"Currently, many home monitoring systems employ cameras, which are intrusive," says Danny Chu, BITWave senior engineer. "But with this audio monitoring we are able to deploy such devices in personal spaces in the homes and yet not intrude on privacy."

The system records all sounds through a series of nodes. An algorithm processes the sounds into digitized signals that can be characterized within a library of activities such as bathing, sleeping, watching television—or falling and calling out for help. The characterized information would be uploaded to the Internet, where someone with access through a mobile phone could be updated on the safety of a family member.

At Nanyang Optical, the glasses designed by Yang Wah Kiang have been praised for their elegant shape and their engineering.

The world's first eco-frames made from almost 100% recycled material.

All versions of this high-end eyewear contain patented screwless systems that attach the frame front to the temple piece.

Nanyang Optical received assistance from SPRING Singapore, and in collaboration with A*STAR to develop the first ever eco-frame, made from nearly 100 percent recycled materials, marketed as LinkSkin. One challenge the company overcame was converting industrial plastic waste into flat plastic sheets for eyewear frames.

"Our R&D team spends a lot of time on these product developments," says company founder Yang. "It's a passion and the determination to do something different and compete internationally in the eyewear arena."

The product was successfully launched at a premier Milan optical show in May 2008. Nanyang Optical has since secured a partner in France, and orders have been received from major European market players such as Lamy (France), and MyVision (Italy).

Zhang Yu, a researcher with A*STAR Institute of High Performance Computing, takes a photo of you. In a flash, a 3D image of yourself is displayed on his computer.

I²R researchers are working on a program to detect terrorist events in subways.

"Current software may take five or ten minutes to transform a 2D image into 3D," says Zhang. "Our technique allows this to be done in an instant."

His technique is based on the scanned data of real people. This makes the software robust and dynamic—it becomes more accurate as it is fed with more data.

Zhang reckons that the applications for his software are wide-ranging, such as for character modelling in gaming and movies, and even for facial surgery planning.

Over at I²R, researchers are working on a program to detect potential terrorist events in subways, in collaboration with government agencies. Says team leader Karianto Leman, "You want intelligence to automatically pick up potential trouble such as somebody leaving a bag behind, or people collapsing from gas attacks."

Similar systems exist, but they use stationary cameras on a rigid platform. A moving subway train presents challenges, such as constantly-changing scenery that is visible from the train's windows and drastic transitions between above and underground.

His team relies on gradients or silhouettes to extract humans and objects, instead of color. Comparisons are made between normal and potential terrorist scenarios, and alarms triggered. The team expects the technology to be rolled out by the end of 2008.

To learn more about the exciting developments in Singapore, visit:

- **Agency for Science, Technology and Research (A*STAR)** — **www.a-star.edu.sg**
- **Economic Development Board (EDB)** — **www.edb.gov.sg**
- **JTC Corporation** — **www.jtc.gov.sg**
- **Media Development Authority (MDA)** — **www.mda.gov.sg**
- **SPRING Singapore** — **www.spring.gov.sg**

World-class destination

The rapid growth of science and technology in Singapore has attracted an increasing number of scientific meetings, conventions and exhibitions.

Riding on its high international standing in water technologies, the country hosted the inaugural Singapore International Water Week (SIWW) in June 2008. Led by the Public Utilities Board (PUB) and supported by the Singapore Exhibition and Convention Bureau (SECB), a group of the Singapore Tourism Board, the event was the result of close collaboration between universities, government agencies and the private sector.

More than 8,500 participants attended the event, including government officials from around the region. Twenty-seven new international agreements, including a water fund for the region, were drawn up. Singapore and the United Arab Emirates also signed a bilateral agreement to cooperate on water research and management, environmental protection, and sustainable development.

The success of this inaugural show sees the SIWW becoming an annual event, with the next show to be held from June 22 to 26, 2009.

"This was a niche we wanted to fill, by looking at the possibilities of a water exposition which would bring together policymakers, industry leaders, and experts to discuss water solutions on a global platform," says Melissa Ow, director of the Industry Planning and Development Division at the SECB.

Her agency looks at the industries that are relevant to scientific expertise within Singapore and brings in meetings, incentive travel groups, conventions, and exhibitions (MICE) that are aligned to these industries. These include digital media, biomedical sciences, transport and logistics, and environment and water technology. "It's part of a development strategy that we have for Singapore as a whole," adds Ow.

In the area of biomedical sciences, Keystone Symposia, a nonprofit scientific conference organization founded in 1972, selected Singapore as its choice to host the organization's first conference ever held outside North America.

The main draw was Singapore's growing international prominence in the life sciences.

The first Keystone Symposium in Singapore was held in October 2005 on the topic "Stem Cells, Senescence, and Cancer." Keystone Symposia has since returned to Singapore for more meetings, most recently in October 2008. Two more meetings in Singapore are planned over the next few years.

Says Ow, "If you look around Asia, you will not find another destination, another city, where you have science, technology, and biomedical research facilities and expertise, all housed within a few kilometers of each other."

This expertise coupled with first-rate MICE facilities including state-of-the-art convention centres, exhibition halls, and meeting venues that are close to accomodations, food, shopping, and entertainment options, explains why Singapore was ranked, for the first time, as the "Top International Meeting City" by the Union of International Associations in 2007. It has also consistently been ranked "Asia's Top Convention City" by international associations like the International Congress and Convention Association and the Union of International Associations.

Key upcoming events include Carbon Forum Asia, Enviro Asia, Cityscape Asia, and the World Dental Congress.

Ow describes two new resort developments, the Marina Bay Sands™ and Resorts World at Sentosa, which will add to the current suite of MICE facilities in Singapore. A host of developments coming up over the next two years will also transform Singapore's landscape and complement its variety of parks, shopping destinations, and river walkways. "We know that what makes a great destination for a business event is also the leisure experience the city provides," reflects Ow. "Singapore provides just such an experience."

For more information on business events in Singapore, www.visitsingapore.com/businessevents.

SOFTWARE

WHAT DOES APPLE WANT?

Programmers bemoan the fickleness of the iPhone's gatekeepers

IN MARCH, when Apple opened the iPhone up to third-party applications, it yielded little control over the popular gadgets: iPhone applications are subject to Apple's approval and can be downloaded only from Apple's Internet-based App Store.

Now, developers are complaining about what they see as Apple's capricious rejection of promising apps. Some have been turned down because they "duplicated the functionality" of proprietary Apple applications, even though the same is true of notepad apps, stock tickers, and the like available through the App Store. A program from the German developer Dirk Holtwick, which let Web applications access the iPhone's hardware, was rejected for being "of limited utility," while apps like iBeer *(right)* were deemed useful enough.

"It's almost like a nightclub, and we're uncertain how we get past the bouncer," says Brit Gardner of the Dallas development company Figaro Interactive. And, many developers argue, that uncertainty stifles innovation. "If you spend a lot of time and a lot of money developing an application, and in the end it's not accepted by Apple, and you don't know why, that's an investment that's worthless," says Holtwick. "So you think twice about creating an application." *–Larry Hardesty*

DAN SAELINGER

USEFUL? Apple has rejected iPhone apps for "limited utility"—but one that lets users feign chugging a beer wasn't among them.

ENERGY

NEW NUKES

The U.S. nuclear industry hopes that safer reactor designs can end decades of stagnation

FOR MORE than 30 years, no one has begun construction on a new nuclear reactor in the U.S. But amid growing concern about energy supplies, the U.S. Nuclear Regulatory Commission (NRC) has registered applications for licenses to build 25 new reactors since July 2007.

Two of the reactor designs specified in the applications feature passive safety systems, which are activated by natural forces and are intended to remove the risk of operator error or malfunctioning electronics. Of these, only one has been approved by the NRC: the Westinghouse Advanced Passive 1000, or AP1000 *(above right)*. The first AP1000 is likely to be built in China, where construction is scheduled to start in March 2009.

A second design, from GE Hitachi, takes passive safety even further, eliminating pumps and relying on natural circulation of water and steam for cooling during normal operation. The reactor has yet to be approved by the NRC, but GE Hitachi says that it has been selected by four U.S. utilities for "potential projects" and is under consideration in Europe. *—Rob Edwards*

IN WESTINGHOUSE'S AP1000 reactor, if a pipe leading to the reactor vessel bursts and releases radioactive steam into the steel reactor containment (green), several emergency systems are activated automatically.

1. As steam escapes, falling pressure within the reactor's pipes causes a backup tank to send water to the reactor. If the pressure continues to fall, a second backup tank releases its contents.
2. If the containment grows hotter, it heats the air above it, which exits through an aerial opening, drawing in cool air (blue arrows) from outside.
3. Water to cool the containment is drawn down by gravity, eliminating the need for pumps.
4. Rising steam (pink arrows) is cooled and condenses, falling back (purple arrows) to the floor.
5. A sump pumps water from the containment floor back into the system. If initial safety measures fail to stabilize the reactor core, the sump works in reverse, flooding the reactor vessel with water.

PASSIVE ACTIVITY

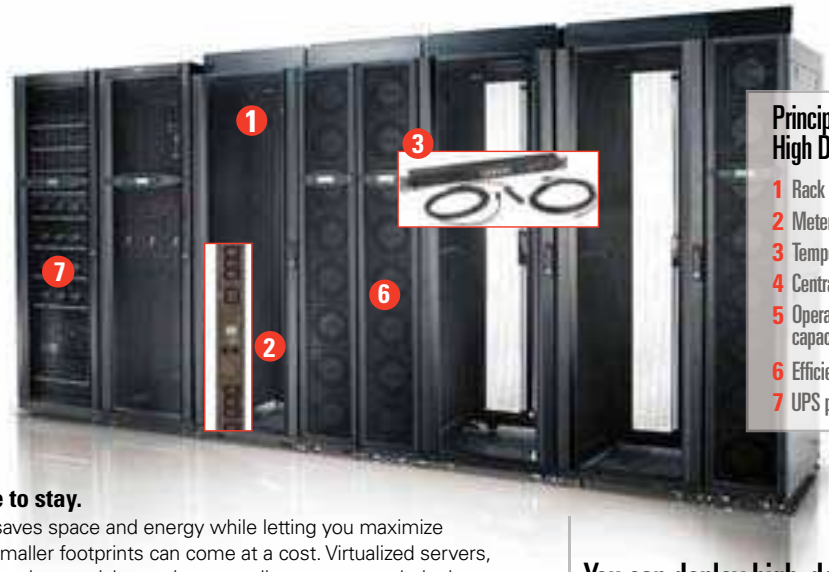
Passive-safety reactors predominate among new applications

Reactor	Manufacturer	Number of U.S. license requests	Major innovations	Status
Advanced Passive 1000	Westinghouse	12 at 6 sites	Simplified design with emergency cooling driven by gravity	Design approved in U.S.; construction due to start in China in March 2009
Economic Simplified Boiling Water Reactor	GE Hitachi	6 at 5 sites	Uses natural circulation to cool reactors during normal operation	Design under review in U.S.; none built
Evolutionary Power Reactor	Areva	3 at 3 sites	More-powerful reactors and higher pressure in steam generators	Design under review in U.S., under construction in Europe
Advanced Pressurized Water Reactor	Mitsubishi	2 at 1 site	Neutron reflector to enhance nuclear reaction	Design under review in U.S.; two license applications in Japan
Advanced Boiling Water Reactor	General Electric	2 at 1 site	Large vessel with no external recirculation pumps	Design approved in U.S., built in Japan

JOHN MACNEILL

Virtualization is only half the battle for efficiency.

InfraStruXure®
DATA CENTERS ON DEMAND



Principles of InfraStruXure® High Density-Ready Architecture...

1. Rack enclosures that are HD-Ready
2. Metered PDUs at the rack level
3. Temperature monitoring in the racks
4. Centralized monitoring software (not shown)
5. Operations software with predictive capacity management (not shown)
6. Efficient InRow® cooling technology
7. UPS power that is flexible and scalable

Virtualization is here to stay.
And it's no wonder – it saves space and energy while letting you maximize your IT resources. But smaller footprints can come at a cost. Virtualized servers, even at 50% capacity, require special attention to cooling, no matter their size or their location.

1. **Heat** Server consolidation creates higher densities – and higher heat – per rack, risking downtime and failure.
2. **Inefficiency** Perimeter cooling can't reach heat deep in the racks. And over-cooling is expensive and ineffective.
3. **Power Events** Virtual loads move constantly, making it hard to predict available power and cooling, risking damage to your network.

The right-sized way to virtualize.
With the new HD-Ready InfraStruXure architecture, you can take on high-density by cooling the virtualized high-density row, controlling power at the rack level, and managing the system with advanced software and simulation. Though virtualizing saves energy, true efficiency also depends on the relative efficiencies of power, cooling, and servers. Right-sizing one and not the others (See Figure 1) leaves efficiency savings on the table. To right-size, depend on the efficient, modular HD-Ready InfraStruXure and neutralize heat at the source. Equipment will be safer and more efficient running closer to 100% capacity.

Don't agonize, virtualize.
What are you waiting for? With HD-Ready InfraStruXure architecture anyone can virtualize… anytime, anywhere. Just drop it in and go.

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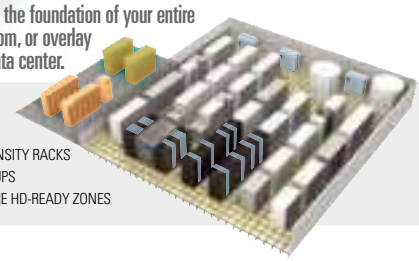


Figure 1

Efficiency and Virtualization

Your servers are efficient, but is your power and cooling?

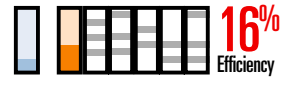
COOLING USAGE/CAPACITY
SERVERS
POWER USAGE/CAPACITY

Pre-Server Virtualization
Big gains could be made with both server and power and cooling.

- ☐ Correct Server Utilization
- ☐ Correct-sized Power
- ☐ Correct-sized Cooling

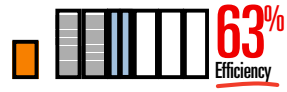
Post-Server Virtualization
Grossly oversized power and cooling cancels out potential gains made by virtualizing.

- ☑ Correct Server Utilization
- ☐ Correct-sized Power
- ☐ Correct-sized Cooling



Server Virtualization with Power and Cooling
Right-sized power and cooling tip the balance back in your favor.

- ☑ Correct Server Utilization
- ☑ Correct-sized Power
- ☑ Correct-sized Cooling



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MEDICINE

HARD ROAD FOR MEDICAL TREATMENTS

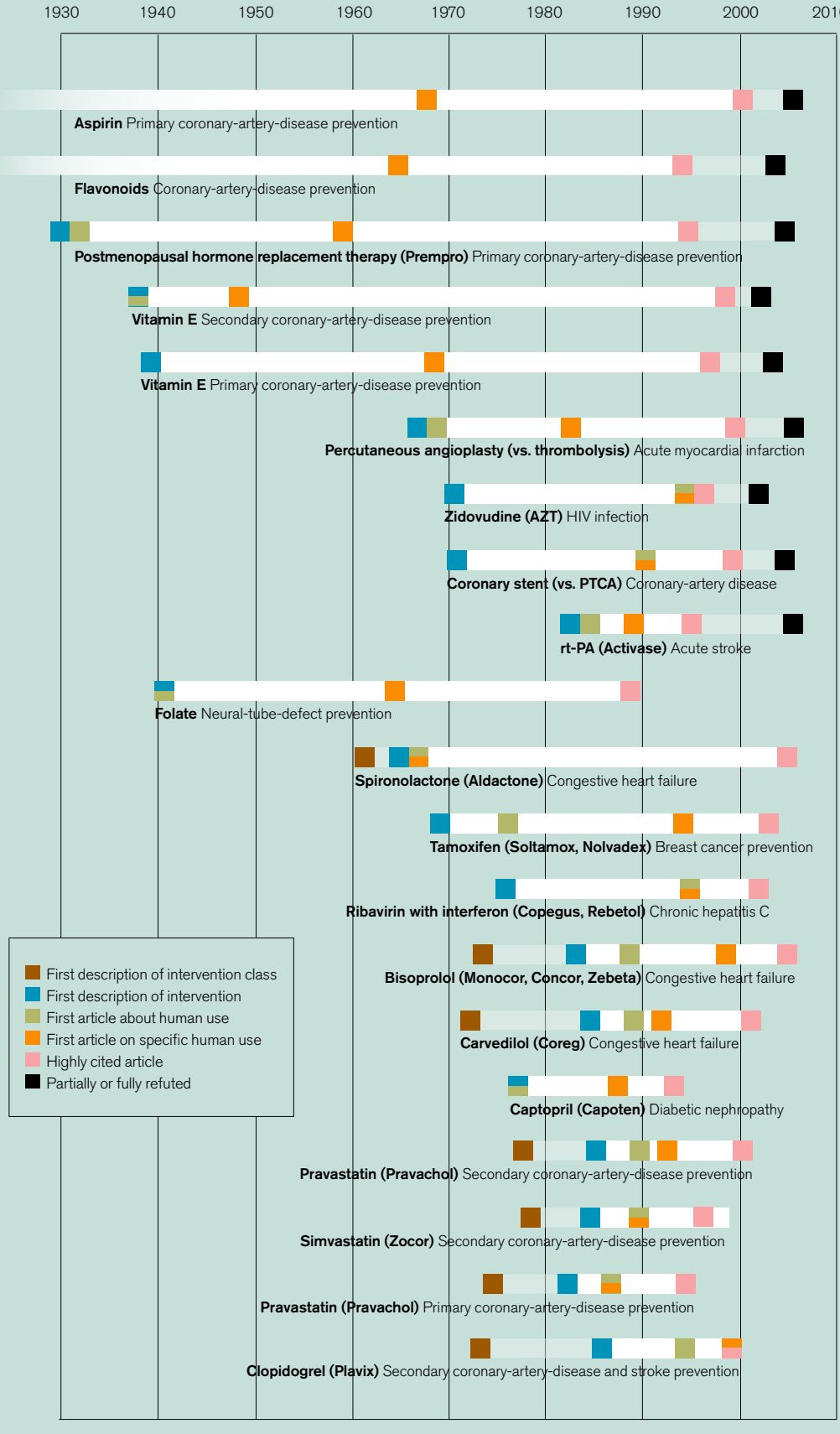
Promising studies are often refuted later

ONLY A TINY fraction of the compounds tested for different diseases ever make it to clinical trials. Now a report in *Science* suggests that the results of even encouraging clinical trials are later refuted with surprising frequency.

Scientists from the University of Ioannina School of Medicine in Greece analyzed published studies, from 1990 to 2004, of promising new drug candidates or medical devices. (A sampling is shown at right.) Of 32 interventions described in these papers, each of which had been cited more than 1,000 times, 13 were later shown not to work or to be less effective than originally thought.

Seven of the studies investigated new applications of well-known compounds; of these, six were later refuted. The report concludes that studies of new compounds and devices are a better use of research money.

"For common diseases, continuing to play with old agents and interventions is unlikely to give us much hope for finding some major effective intervention that we were not already aware of," says John Ioannidis, senior author of the study. *–Emily Singer*



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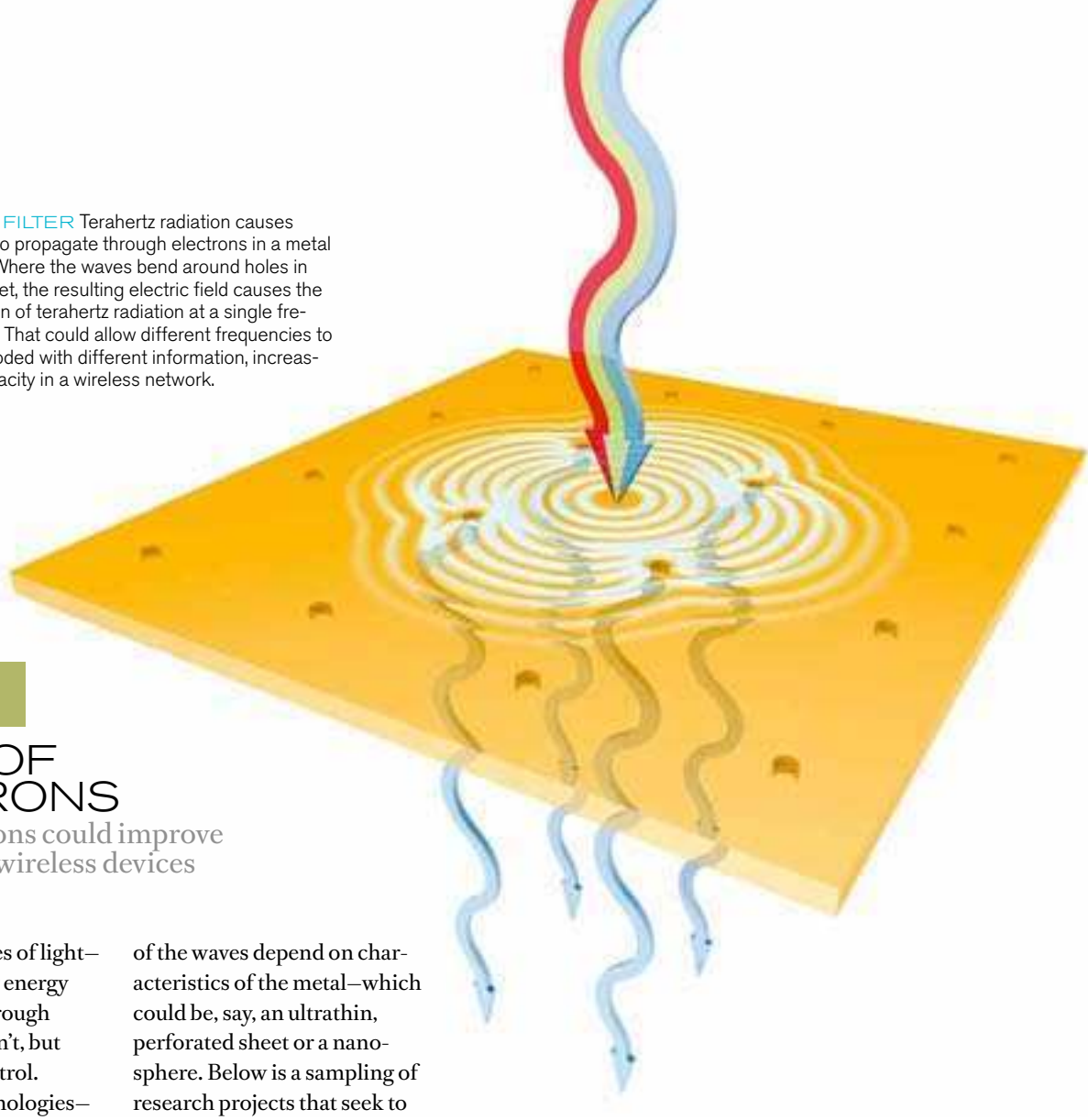

T-RAY FILTER Terahertz radiation causes waves to propagate through electrons in a metal sheet. Where the waves bend around holes in the sheet, the resulting electric field causes the emission of terahertz radiation at a single frequency. That could allow different frequencies to be encoded with different information, increasing capacity in a wireless network.

PHYSICS

WAVES OF ELECTRONS

Surface plasmons could improve solar cells and wireless devices

PHOTONS—particles of light—are good at carrying energy and information through space; electrons aren't, but they're easier to control. Many modern technologies—imaging systems, solar cells, information networks—need to mediate between footloose photons and well-behaved electrons, but getting the particles to interact with each other can be a challenge.

Recently, researchers trying to bridge the photon-electron divide have been turning to a peculiar physical entity called a surface plasmon, which is like a wave passing through the cloud of electrons on the surface of a metal. Phenomena such as light shining on a sheet of metal induce plasmons, much the way dropping a stone in a pond induces waves. The shape and motion of the waves depend on characteristics of the metal—which could be, say, an ultrathin, perforated sheet or a nanosphere. Below is a sampling of research projects that seek to take advantage of the plasmon's versatility. *—Kate Greene*

JACK OF ALL TRADES | Research tries to harness the plasmon

Application	Strategy	Researchers
More-efficient solar cells	Nanoscale metal structures could concentrate plasmonic waves created by sunlight, directing different wavelengths of light to the right solar cells and capturing more energy from light at sharp angles	Harry Atwater (Caltech), Mark Brongersma (Stanford), and Albert Polman (Utrecht University)
Optical computing	To keep photons confined, optical circuits must be much larger than electrical circuits, but converting light into plasmons allows it to squeeze into smaller spaces	Xiang Zhang (University of California, Berkeley); Alexander A. Govyadinov (University of Pennsylvania); Michael Hochberg (University of Washington)
Managing terahertz radiation (for faster wireless communication and safer replacements for x-rays)	The types of devices used to produce and control infrared and microwave light don't work at terahertz frequencies, but researchers have exploited plasmons to produce, guide, and filter terahertz radiation	Ajay Nahata (University of Utah); Qing Hu (MIT)

BRYAN CHRISTIE

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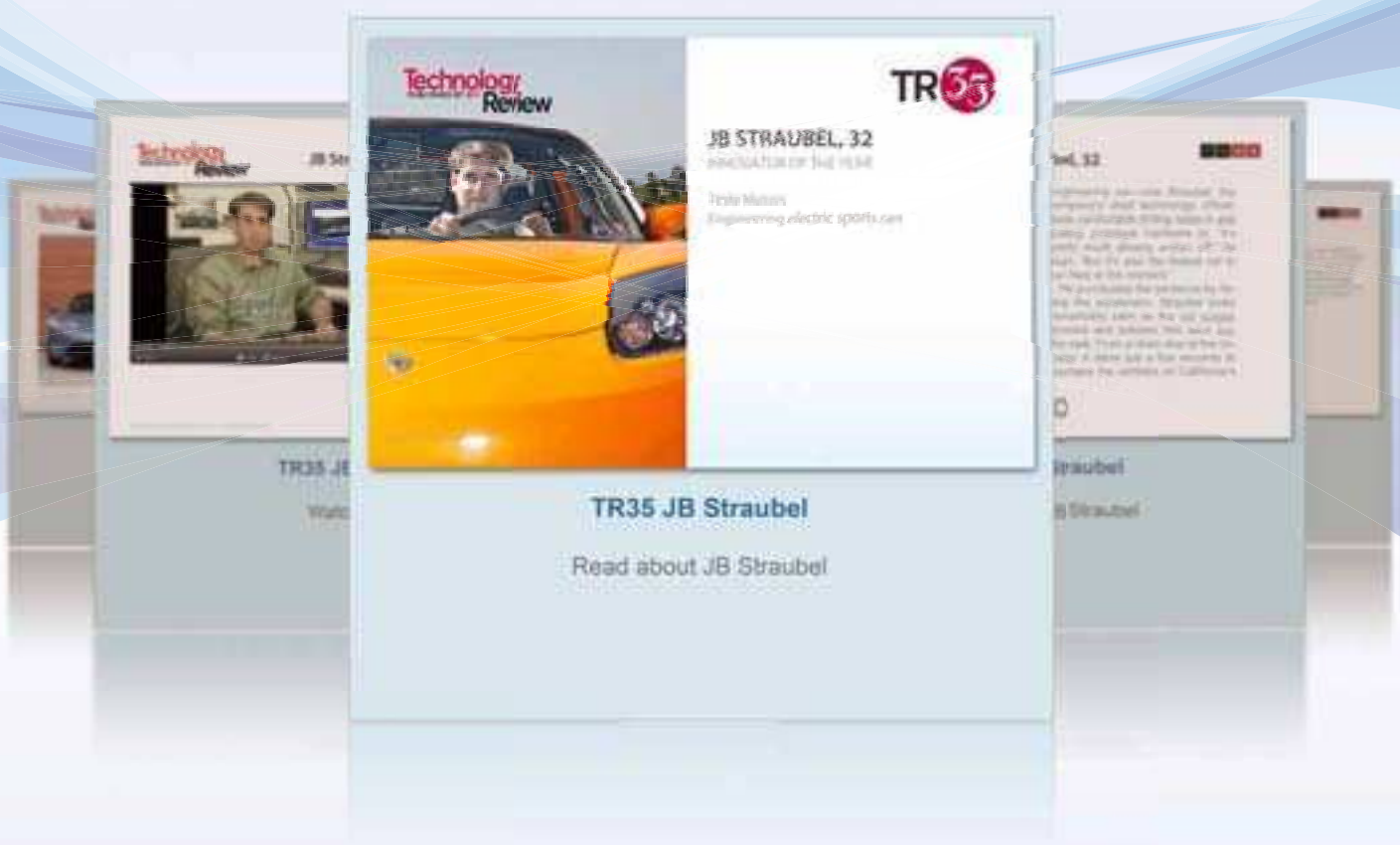

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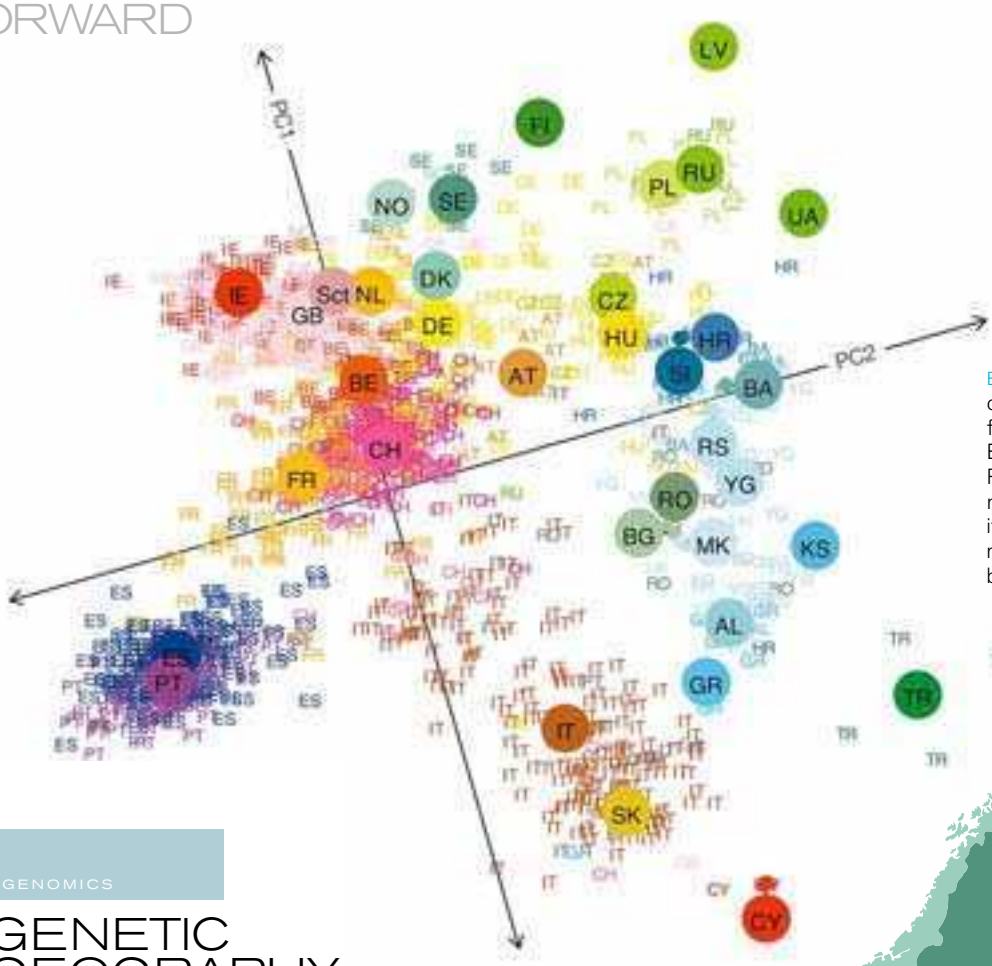


BLOOD WILL OUT A mathematical operation maps the most significant differences between the genomes of 1,387 Europeans onto a single axis (PC1). Performed again, the operation maps the most significant differences that the first iteration missed (PC2). The result—a 2-D map of genetic variation—looks remarkably like a map of Europe.

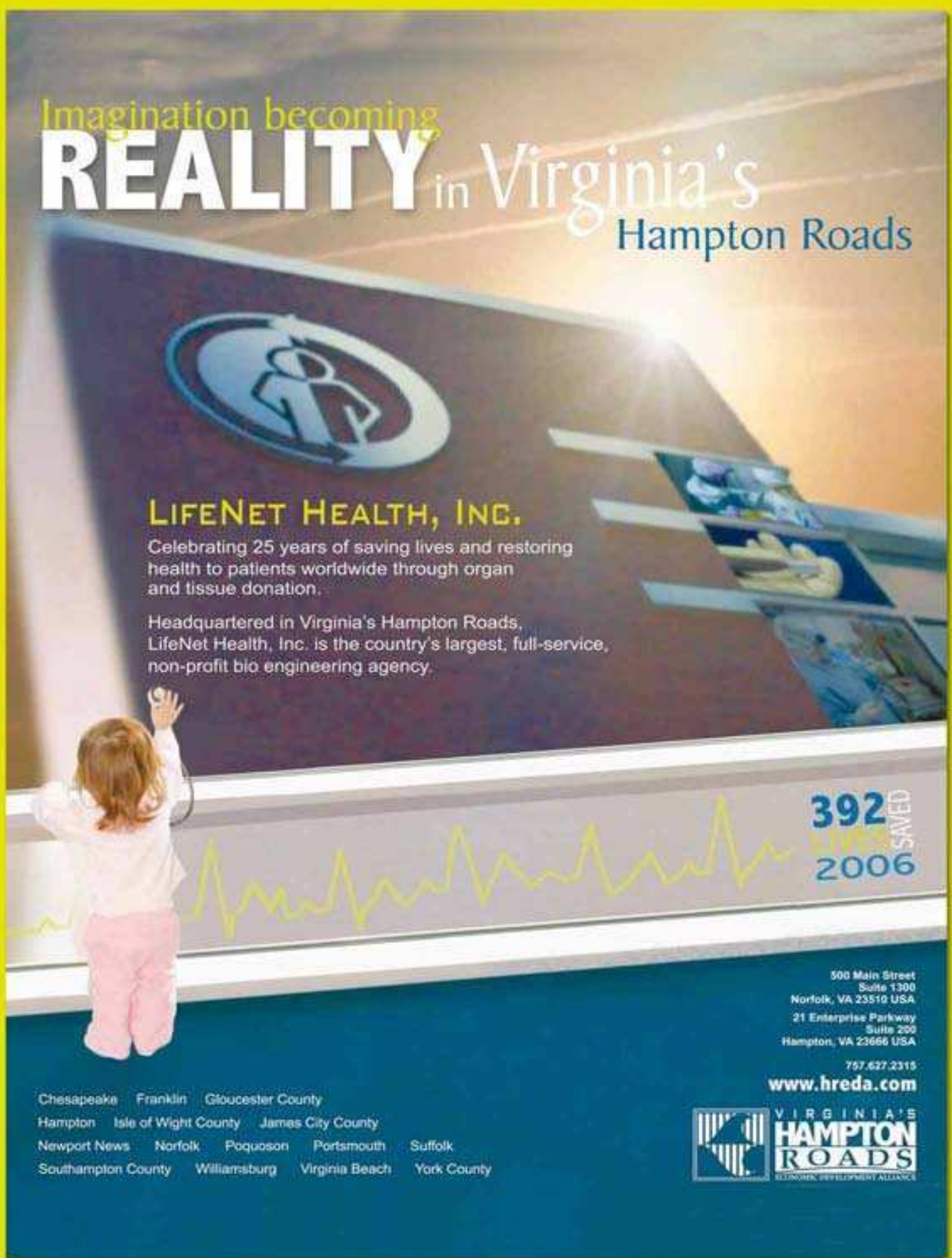
GENOMICS

GENETIC GEOGRAPHY

Genomic analysis reveals Europeans' places of origin

AN INTERNATIONAL group of scientists has shown that genetic analysis can pinpoint Europeans' geographic origins within a few hundred kilometers. The scientists mathematically mapped the differences between people's genomes onto a two-dimensional grid, and the result looked much like a map of Europe.

John Novembre, an evolutionary geneticist at the University of California, Los Angeles, who participated in the study, says that the findings could have research implications. Scientists can study a disease by looking for genetic variations shared by people who suffer from it. But test subjects from different countries may have unrelated genetic variations that yield false positives. The same technique that produced the genetic map could filter out such regional differences, making it easier to home in on variations of interest. –*Larry Hardesty*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STARTUPS

THE VIDEO WEB

Three startups let users layer new content onto online video

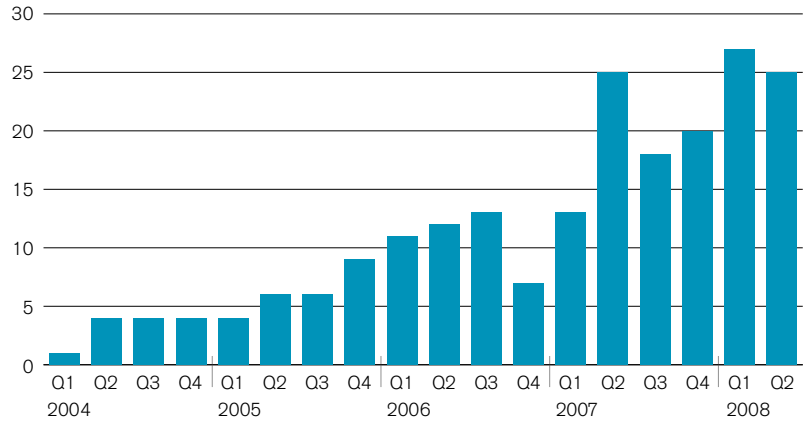
TODAY'S WEB pages feature streaming media, interactive applications, and forums for social interaction—content that Dow Jones's VentureWire, which tracks venture investment, refers to as "information services." Companies that provide those services have seen increasing funding for years.

But according to VentureWire, information services that specialize in entertainment have grown even faster than the sector as a whole, from seven deals worth $42 million in 2002 to 76 deals worth more than half a billion dollars in 2007. Investment in the first half of this year was ahead of even last year's torrid pace.

In part, that growth reflects the recent explosion of online video, which represents more than just a convenient way to watch the same old TV shows: it also opens up the possibility of interacting with video in fundamentally new ways. That's the goal of several companies that received funding in the second quarter of 2008, the last for which VentureWire has data. *—Neil Savage*

THAT'S ENTERTAINMENT

Number of deals, by quarter



Source: VentureWire

BIGSTAGE

BigStage's software was originally funded by the CIA, which wanted 3-D computer models of suspects' faces to match against images in a database. The company's commercial customers take three digital pictures of themselves and upload them to BigStage's servers, and in about 50 seconds, they have a digital avatar that they can insert into videos or photos. Users will be able to post the videos to their Facebook pages or e-mail them to friends; eventually, they should also be able to purchase brand-name virtual accessories for their digital selves.

Product: Digital avatars constructed from still photos
CEO: Phil Ressler
Location: South Pasadena, CA
Funders: Mission Ventures, Selby Venture Partners, Tech Coast Angels
Funding: $2.9 million
URL: www.bigstage.com

PLYMEDIA

Plymedia provides software that lets video producers add content to their videos, whether it's foreign-language subtitles for viewers abroad, closed captions so users can watch the financial news without disturbing their coworkers, or snarky remarks in thought bubbles above politicians' heads. One of Plymedia's more interesting services is TrackIt, which analyzes the music in a video, compares it with files in Sony's Gracenote library of music, identifies the song's title and the artist's name, and displays them along with a link that can be clicked to purchase the song as a music file or ring tone.

Product: Interactive content for online videos
CEO: Ben Enosh
Location: Palo Alto, CA
Funders: Elron Electronic Industries, Greylock Partners
Funding: $8.5 million
URL: www.plymedia.com

VEOTAG

With Veotag's software, a video publisher can embed descriptive tags in a video and display the tags next to the video window as a table of contents, so viewers can skip forward or back to the sections they find most interesting. Below the table of contents is a box that displays additional information or links related to each tag. For example, a publisher could add a link to a set of PowerPoint slides to accompany a CEO's talk about company earnings. The tags provide far more information to search engines than the video's title alone would, making the video more accessible to the public.

Product: Software to embed tags and other content into video
CEO: Scott Rhodes
Location: New York, NY
Funders: Small Ventures USA
Funding: $2.5 million
URL: www.veotag.com

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TO MARKET

CRYPTOGRAPHY

FORGERY-PROOF RFID TAG

A CALIFORNIA company is selling RFID tags that would take a counterfeiter years to duplicate. Microscopic differences between the tags—a side effect of normal manufacturing techniques—mean that each will yield different answers in a set of test calculations. A forger would have to correctly predict the results of 16 billion billion such calculations to be sure of accurately simulating a single tag. The tags are being marketed as a way for manufacturers to authenticate brand-name luxury goods.

Product: Vera X512H
Cost: Around 12 cents, depending on volume
Source: www.verayo.com
Company: Verayo

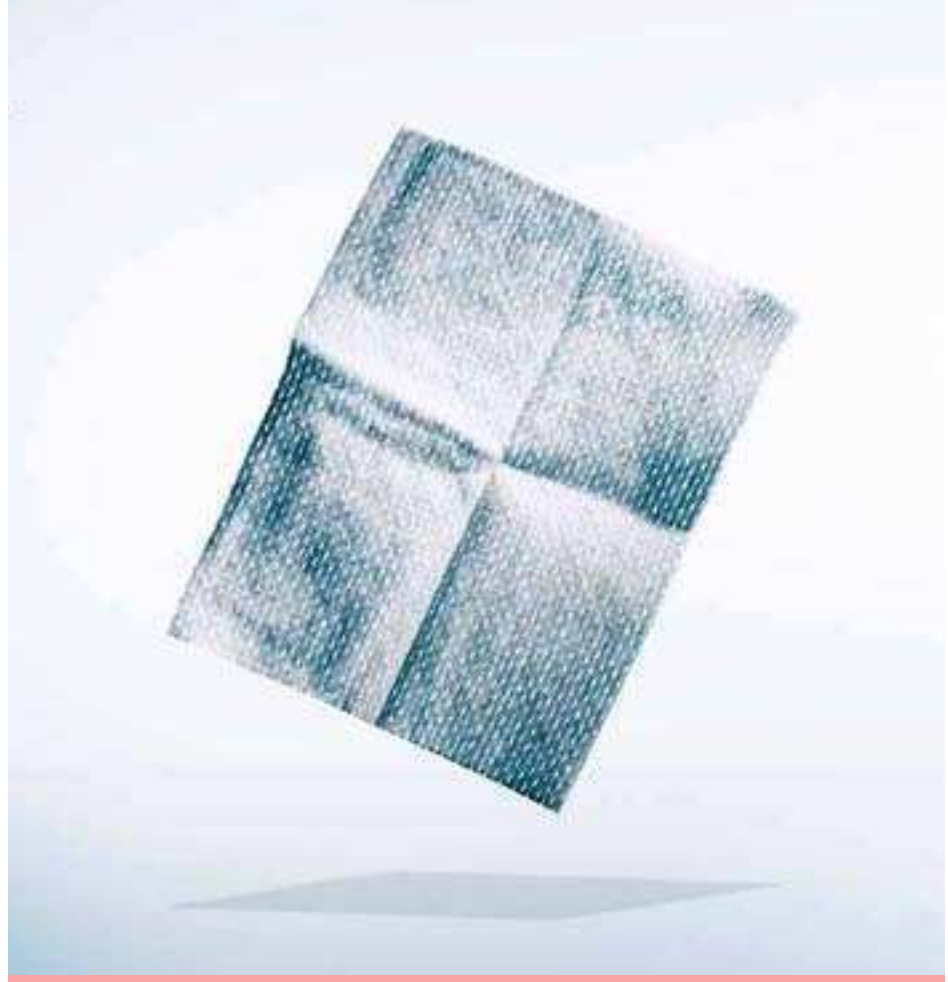
DAVID ARKY

DISPLAYS

Color E-Paper Debuts

A WATERPROOF MP3 player built for bright beach days is the first device with a color "e-paper" display, meaning it has no backlighting and thus can be read in direct sunlight. The display, from Qualcomm, consists of two layers of a reflective material. Some wavelengths of light bounce off the first layer; some pass through and bounce off the second. Interference between the two beams creates the color, and electrostatic forces control the distance between the layers.

Product: Freestyle Audio player
Cost: Around that of Freestyle's previous players, which range from $80 to $100
Source: freestyleaudio.com
Company: Freestyle Audio, Qualcomm



MEDICAL SUPPLIES

BLOOD-STANCHING GAUZE

A CUTTING-EDGE technology designed for the battlefield is now commercially available—and its first application is stopping nosebleeds. The gauze from Z-Medica is infused with tiny particles of a clay called kaolin, whose ability to stop bleeding was discovered by Galen Stucky, a chemist at the University of California, Santa Barbara. Before making its commercial debut, the gauze was used by the U.S. military, whose Tactical Combat Casualty Care program recommends it for hemorrhage treatment.

Product: QuikClot NoseBleed **Cost:** $11.49 for a box of five applications **Source:** quikclot.com **Company:** Z-Medica

IMAGING

FIRST POCKET ULTRASOUND

SIEMENS HOPES that its miniaturized ultrasound device, which can fit in a physician's coat pocket, will become the stethoscope of the 21st century. Doctors could use it during routine exams, nurses could use it for triage in the emergency-room lobby, and emergency medical technicians could use it at the sites of accidents. Siemens says the key to miniaturization was a proprietary display technology that produces clear images even at small sizes.

Product: Acuson P10
Cost: $25,000 Canadian
Source: www.medical.siemens.com/us
Company: Siemens

DAVID ARKY (GAUZE); COURTESY OF QUALCOMM (E-PAPER); COURTESY OF SIEMENS (ULTRASOUND)

SPOTLIGHT ON INNOVATION - A TECHNOLOGY REVIEW CUSTOM SERIES

The Technology Review Custom Team takes a look at the technologies that are changing the ways in which we do business. The first article of four focuses on clean energy and takes a look at the advancements in the wind, biofuel, and solar sectors.

CLEAN ENERGY

As the energy debate rages in political and scientific circles, investment in clean energy technologies continues to rise. Clean Energy Trends 2008, published by research firm Clean Edge, estimates that wind energy, biofuels, and solar photovoltaics (PV)—a combined $75.8 billion market in 2007—will increase to $238.5 billion, within a decade. Yet it remains to be seen which clean energy technologies have the brightest commercial future.

A GUST IN WIND ENERGY

Wind power, whose new-installation capital costs were estimated at $30.1 billion in 2007, is projected to expand to $83.4 billion by 2017. It's a prospect that investors like oil and gas titan T. Boone Pickens are banking on. He aims to build the world's largest wind farm—up to 2,000 turbines—in Texas.

Currently, the largest player in wind energy in the United States is Florida-based FPL Group. Its subsidiary FPL Energy has nearly 60 wind facilities in North America. These turbines have a generating capacity equivalent to 30 percent of the nation's wind-generated electricity. The company intends to add 8,000 to 10,000 megawatts by 2012.

"[Wind energy] is an important element of our growth strategy," says FPL Energy spokesman Steve Stengel. "By the end of this year, we will have approximately $8 billion invested in our wind business."

NEW APPROACHES TO BIOFUEL

It's estimated that the biofuels market will increase from $25.4 billion to $81.1 billion by 2017. However, opinions differ on what the biomass feedstock of choice will be.

At the University of Georgia, researchers recently announced an acid-free pretreatment technology that significantly increases the simple sugars released from grasses for conversion to ethanol. It's a discovery that builds upon claims scientists made at BioMass 2008: the best energy yields come from native grasses, not corn or soy.

Meanwhile, 2008 has proved a banner year for algae-based biofuel, attracting $179.5 million in venture capital as of September, according to the Cleantech Group.

The technology behind PetroAlgae, a company based in Melbourne, FL, sidesteps the food-versus-biofuel dilemma, since algae does not require arable land. PetroAlgae claims it can produce 200 times more oil per acre per year than is possible with soybean-based biofuel. This oil can be used in many applications, including transportation, bioplastics, and cosmetics.

In Boca Raton, FL, Citrus Energy president David Stewart plans to take advantage of the five million tons of citrus waste the state generates each year by building a first-of-its-kind commercial-scale plant that turns orange and grapefruit peels into ethanol. Once in operation, the facility's equipment will also be used for further research on energy crops during the citrus off-season.

"Citrus peel does not carry the carbon and energy burdens of having to plant, fertilize, harvest, and transport a dedicated feedstock for ethanol production," Stewart says.

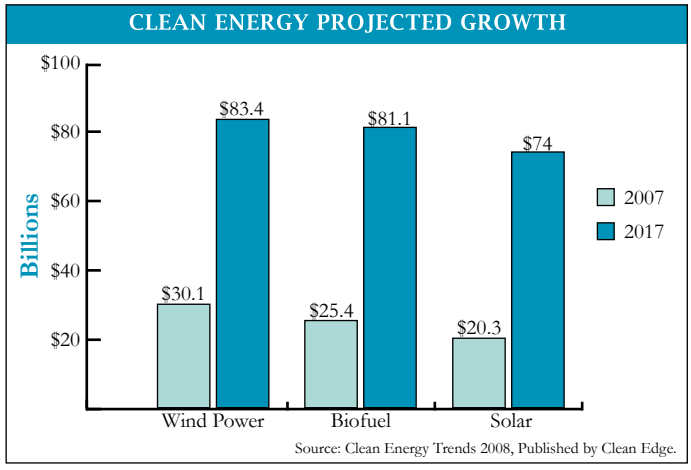
LOOKING TO THE SUN

There are those who believe that becoming independent of fossil fuels will require a portfolio approach, with much of that portfolio invested in solar energy—a market that's estimated to grow to $74 billion by 2017.

As of next year, Florida will host the world's largest solar PV plant. The DeSoto Next Generation Solar Energy Center, which will generate 42,000 megawatt-hours of electricity annually, is under construction in DeSoto County. With 240 days of sunshine and 85 percent of the maximum solar resource available in the country, Florida has become a hub for research centers and businesses exploring next-generation solar technologies.

One example is the University of South Florida's Clean Energy Research Center, which studies thin and thick films, silicon carbide materials and processing, photovoltaic and hybrid systems, tandem solar cells using organic polymers and inorganic materials, and rooftop systems. Researchers here were first in the world to exceed 15 percent efficiency for a thin-film PV cell using cadmium telluride.

No matter which technologies push to the forefront, it's evident that fossil fuels are no longer the only players in the energy market. The International Energy Agency estimates that $600 billion needs to be invested annually to meet the projected demand for new electricity and fuel sources worldwide. With such a great need, companies that make it their business to produce clean energy are certainly positioning themselves for a greener future.



INTERFACES

Projector Connector

A TAIWANESE company wants business travelers to leave their laptops at home. Its new pocket-sized device plugs into a TV or projector and wirelessly downloads PowerPoint slides or streaming video from a smart phone, which acts as a remote control. The device comes with software that modifies the phone's video output so that it has high enough resolution for a big screen. It can also work with computers, however, streaming high-definition videos to a TV.

Product: MobiShow **Cost:** Less than $200 **Source:** www.awindinc.com **Company:** Awind

MATERIALS

NANO-STRUCTURED BONE GRAFT

BONE GRAFTS can more closely mimic the chemical structure and composition of natural bone, thanks to a new material. Like other synthetics, the material minimizes the risk of immune rejection, but it's much better at encouraging cells to grow. Developed by Michigan company Pioneer Surgical Technology, the material is made up of two bonelike components not found in other synthetics: calcium-containing nanocrystals the same size as those in natural bone, and collagen to mimic the soft tissues around natural bone.

Product: FortrOss
Cost: $700 to $4,000 per treatment, depending on size of graft
Source: www.pioneersurgical.com
Company: Pioneer Surgical Technology

OPERATING SYSTEMS

GOOGLE GOES MOBILE

T-MOBILE'S G1 is the first phone to run Google's open-source operating system, Android. It can download third-party applications from the Android Market, Google's counterpart to Apple's iPhone App Store, and its operating system links directly to many of Google's online services, including e-mail, calendar, and maps. The G1 also features a touch screen, GPS, Wi-Fi, a camera, and MP3-playing software.

Product: T-Mobile G1 **Cost:** $179 to $399 (depending on service contract) **Source:** www.t-mobileg1.com
Company: Google, T-Mobile

COURTESY OF AWIND (PROJECTOR); COURTESY OF T-MOBILE (PHONE); COURTESY OF PIONEER SURGICAL (BONE)

MICROMACHINES

MEMS AIR CONDITIONING

AIR CONDITIONERS equipped with a new valve will use up to 25 percent less energy. The valve, which regulates the expansion of liquid coolant, adjusts to changes in temperature and pressure more quickly and precisely than conventional valves can. Its secret: microelectromechanical systems, or MEMS—devices carved out of silicon and known for their precision and speed. MEMS are so small that they can typically control only microliters of fluid. But the new valve, through a series of levers and other mechanical devices, can control the larger volumes needed for air conditioners.

Product: Microstaq SEV **Cost:** Competitive with existing expansion valves, which sell for $15 to $30
Source: www.microstaq.com **Company:** Microstaq

SOFTWARE

Safe Transactions on Infected Computers

YOU'RE ABOUT to go online to make a financial transaction, but you don't realize that your computer has been breached by malicious hackers: it's loaded with malware and spyware. Verdasys believes that its tool, SiteTrust, can intervene at this point to keep your identity safe. SiteTrust buries itself deep in a computer's operating system, where it can take fundamental control of most of the machine's operations. Malware can't attempt to interfere in an online transaction without SiteTrust's knowing.

Product: SiteTrust **Cost:** Free to customers through participating financial institutions **Source:** www.sitetrust.net
Company: Verdasys

SENSORS

ACTIVITY MONITOR

A TWO-INCH accelerometer-equipped sensor from Fitbit lets health-conscious people track their physical activity and the calories they burn; slipped into a wristband to monitor wrist tremors, it can even gauge quality of sleep. A base station connected to the Internet retrieves data wirelessly from the device and uploads it to the Web. Online, users can measure calories consumed against calories burned, or compare their physical activity with that of friends and family.

Product: Tracker
Cost: $99
Source: www.fitbit.com
Company: Fitbit

COURTESY OF FITBIT (MONITOR); DAVID ARKY (MEMS)

Q&A

LINDA AVEY AND ANNE WOJCICKI

The founders of startup 23andMe want to know your genome.

A customer of the Web-based service 23andMe sends in a sample of spit and, for about the cost of a Sony PlayStation 3, receives a genome-wide analysis of nearly 600,000 genetic variations. The results include an estimate of genetic risk for various diseases, along with other personal information, such as where the customer's ancient ancestors might have come from.

The service's $399 price tag and its analysis of some quirky genetic traits, such as type of earwax, epitomize Linda Avey and Anne Wojcicki's populist approach to the genome. Avey, whose expertise is in business development for the biotechnology industry, and Wojcicki, who has a background in health-care investing, have also given the service a twist by harnessing the popularity of social networking; clients can compare their genomes with those of friends and family. *TR* senior editor Emily Singer recently visited Avey and Wojcicki at their offices in Mountain View, CA, to find out what it's like to delve into one's own genome.

What does it mean to share your genome?

Avey: We have two levels of sharing. At the basic level, you don't view specific genetic information, but you can compare yourself across your entire genetic data set. You could look to see if you are part of the same haplogroup [a designation of ancient ancestry] as a friend.

With extended sharing, you open up part of your genome information to others. You might do that with siblings or close friends. For example, we have a feature called family inheritance. If you have data on three generations of a family and plug in all three, you can see how a particular set of genes, like the genes for circadian rhythm, were passed down. If you compare genomes with a sibling, you can see if you received the same chunk of chromosomes from both parents. Siblings look like identical twins at some parts of the genome.

What will be one of the first examples of genetic information someone might use to make a medical decision?

Wojcicki: One of the areas we've talked a lot about is pharmacogenomics—being able to say, should you take ibuprofen? Or if you have a new baby and you're flying to Europe, should that child take Benadryl, or will it make them hyper?

What are the downsides of this kind of genetic testing?

Avey: You could find out the person you thought was your father is not your father. We point that out in the consent form. On the health side, we don't test for more serious conditions like Huntington's disease.

How do you respond to the criticism that it is too early to offer this type of genetic information directly to consumers?

Wojcicki: Part of the reason we started this company is that we want to accelerate the pace of research. We want personalized medicine to be a reality. Instead of being reactive—you have this disease and we're going to treat it—we want to focus on prevention. Are you at high risk for type 2 diabetes? Are there things you can do to prevent that?

WWW Watch Anne Wojcicki and Linda Avey answer questions about 23andMe: **technologyreview.com/qanda**

How would this product accelerate the pace of genomic research?

Avey: We'll have the ability to collect massive amounts of information from customers. We've sent out a few surveys now, and we've been pleased and excited by the response.

What kind of surveys?

Avey: We're starting with broad questions that everyone can answer. "Are you left- or right-handed?" "Are you a night owl or an early bird?"

Wojcicki: I was surprised by the percentage of people that sneeze when they see bright sunlight.

Is that genetically determined?

Wojcicki: We don't know. This is a chance to find out. Because we already have their genetic information in the database, we can start to separate them out into those who sneeze and those who don't, and see if any genes start popping out.

Avey: Future surveys will delve more into specific disease areas, such as Parkinson's disease and gestational diabetes.

23andMe recently cut the price of its service from nearly $1,000 to about $400. Why?

Avey: The cost of genotyping technology is dropping—everything is getting cheaper and faster. We are all about democratizing genetics. The more people we have enrolled, the more quickly we can start making genetic associations of our own.

What have you found most interesting in your own genome?

Wojcicki: Caffeine metabolism is really interesting. I love coffee.

Do you find that fast metabolizers like coffee more?

Avey: I'm a slow metabolizer. I can drink a cup of coffee and go straight to bed, maybe because I just don't metabolize it.

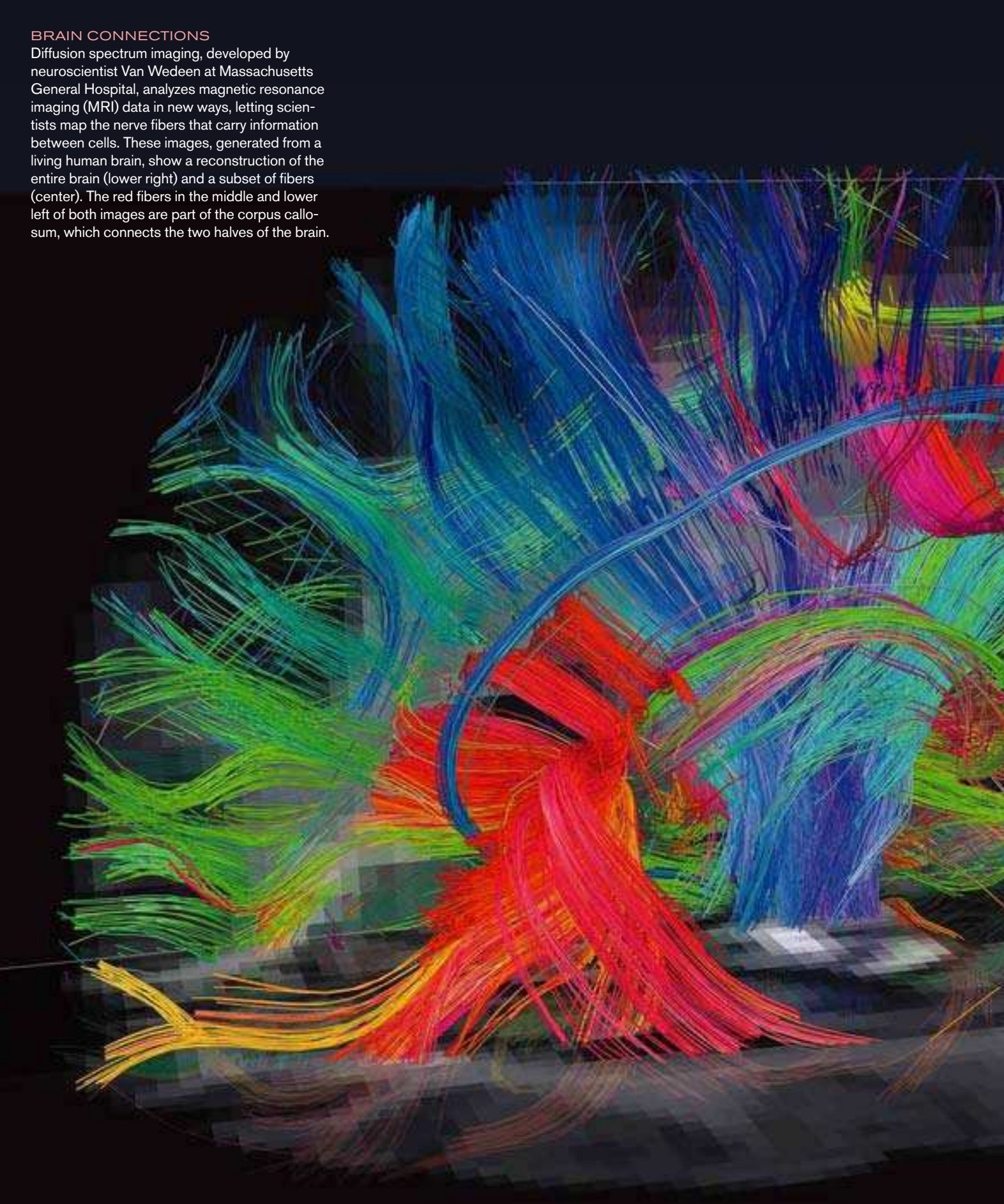
Wojcicki: When I drink coffee, I'm really happy. TR

Photograph by TOBY BURDITT

COFOUNDERS
Anne Wojcicki (left) and Linda Avey of the personal-genomics company 23andMe

BRAIN CONNECTIONS

Diffusion spectrum imaging, developed by neuroscientist Van Wedeen at Massachusetts General Hospital, analyzes magnetic resonance imaging (MRI) data in new ways, letting scientists map the nerve fibers that carry information between cells. These images, generated from a living human brain, show a reconstruction of the entire brain (lower right) and a subset of fibers (center). The red fibers in the middle and lower left of both images are part of the corpus callosum, which connects the two halves of the brain.

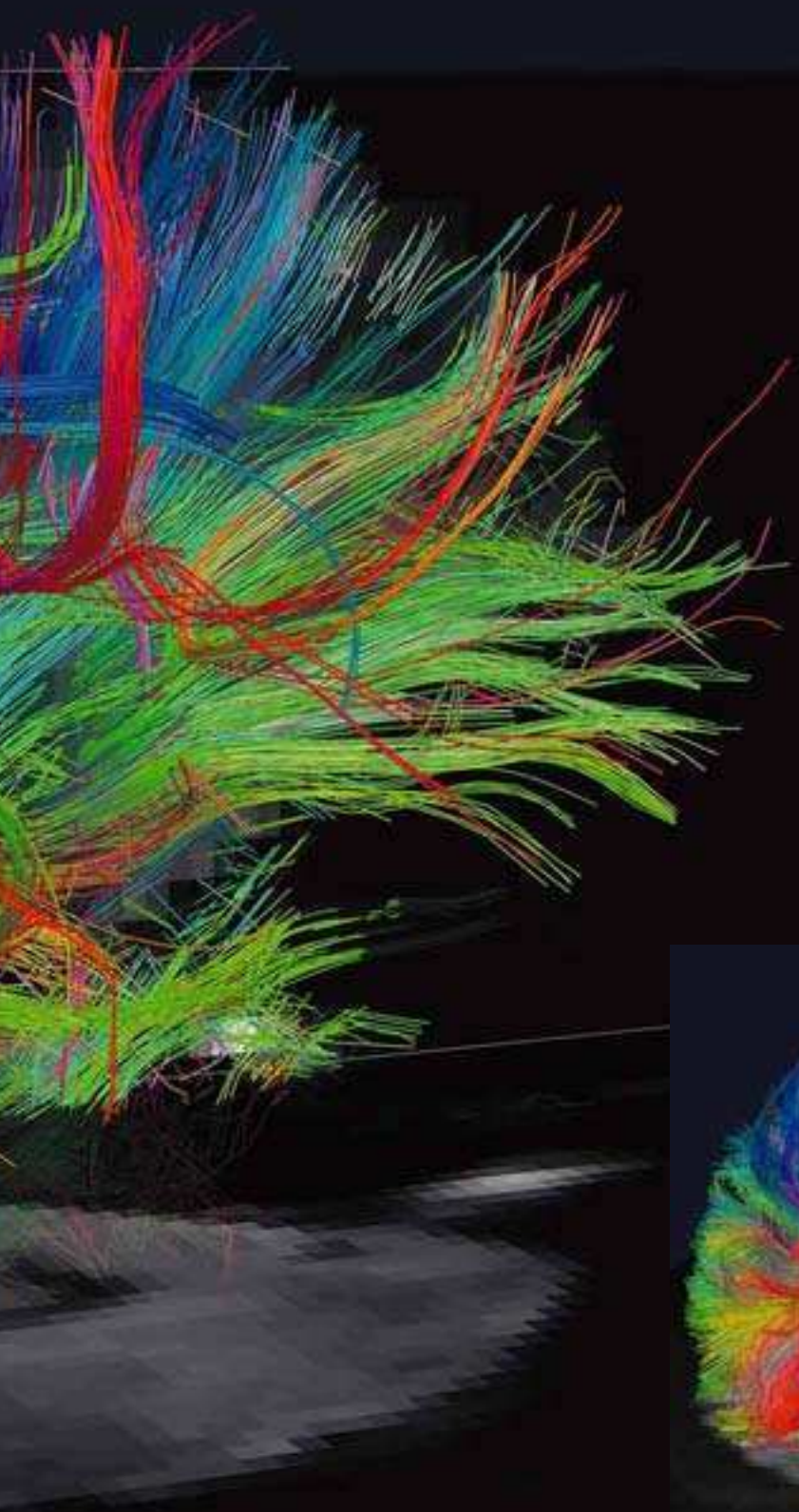


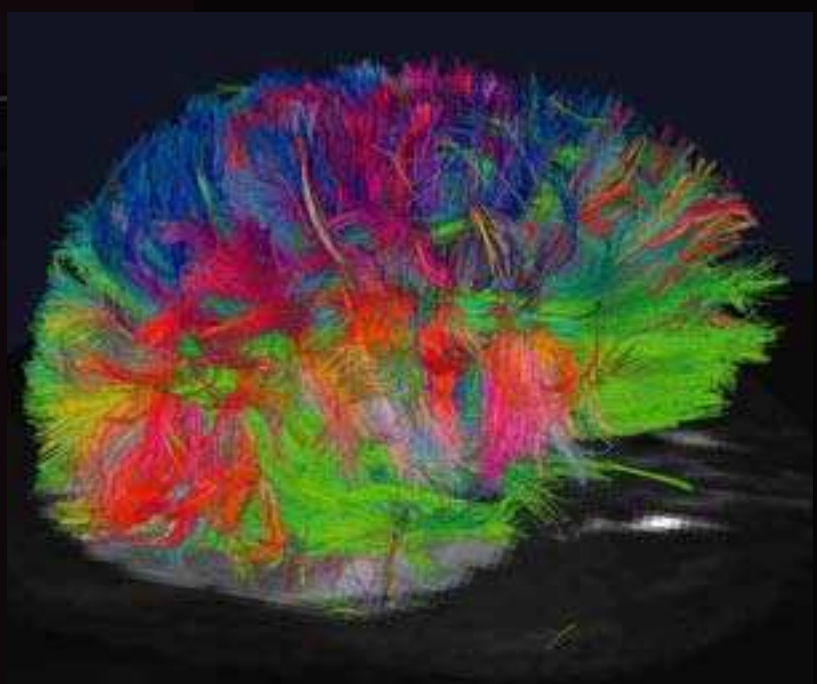
NEUROSCIENCE

The Brain Unveiled

A NEW IMAGING METHOD THAT OFFERS AN UNPRECEDENTED VIEW OF COMPLEX NEURAL STRUCTURES COULD HELP EXPLAIN THE WORKINGS OF THE BRAIN AND SHED LIGHT ON NEUROLOGICAL DISEASES.

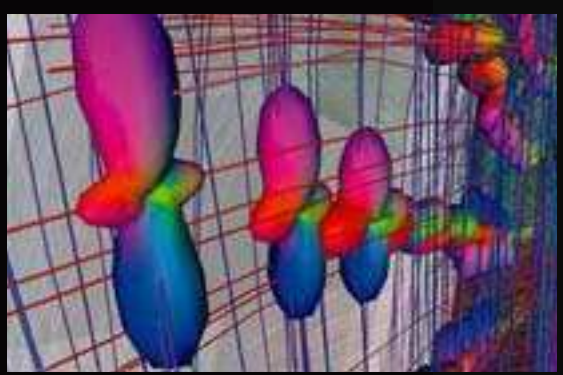
By EMILY SINGER

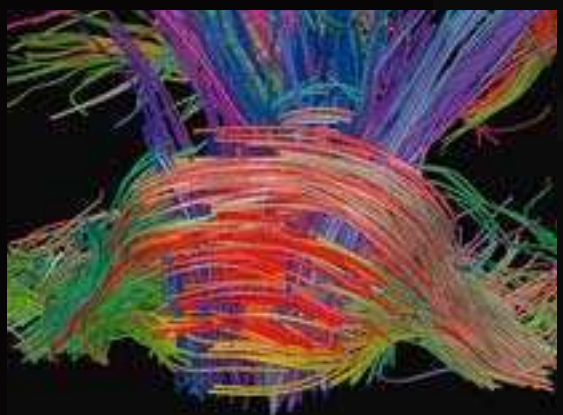


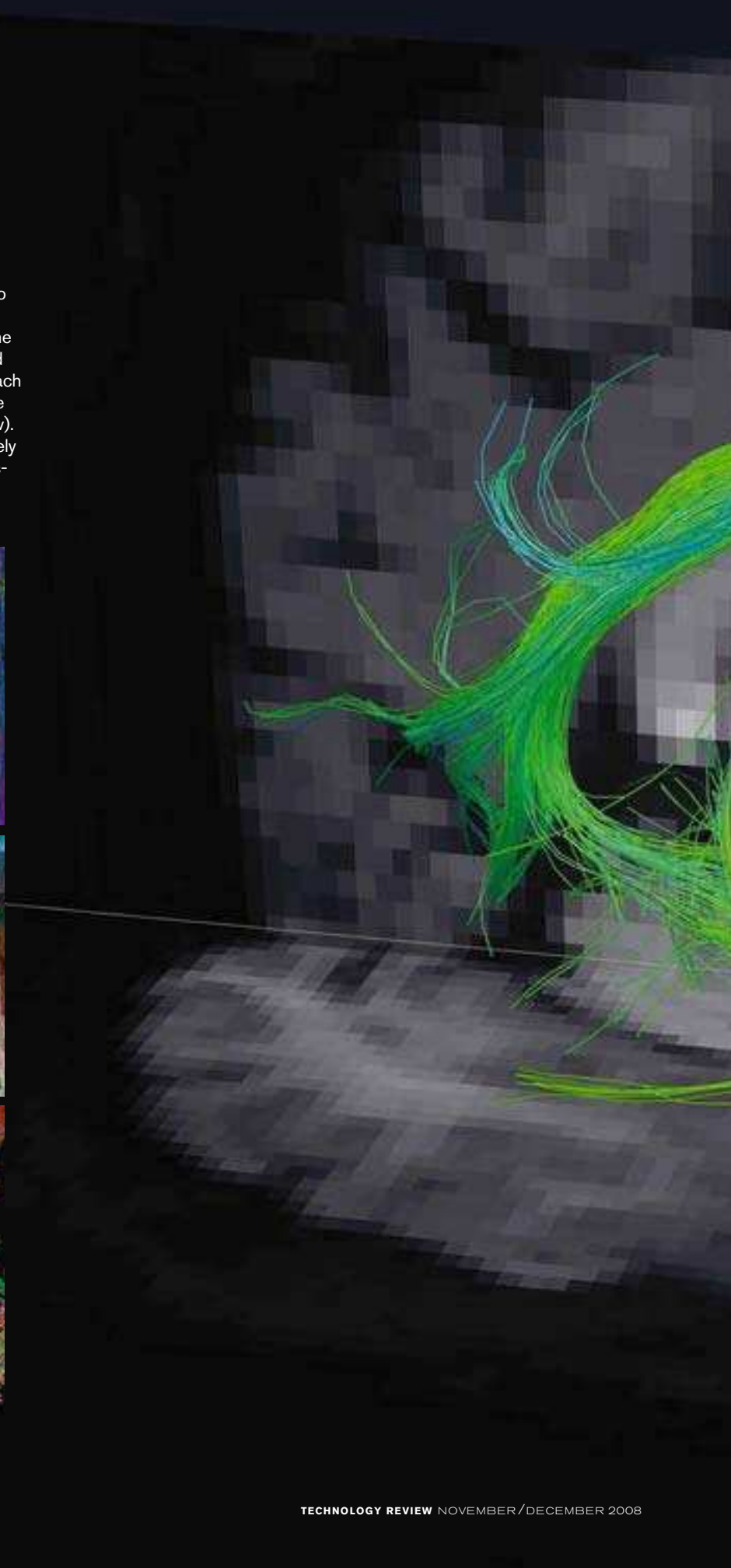


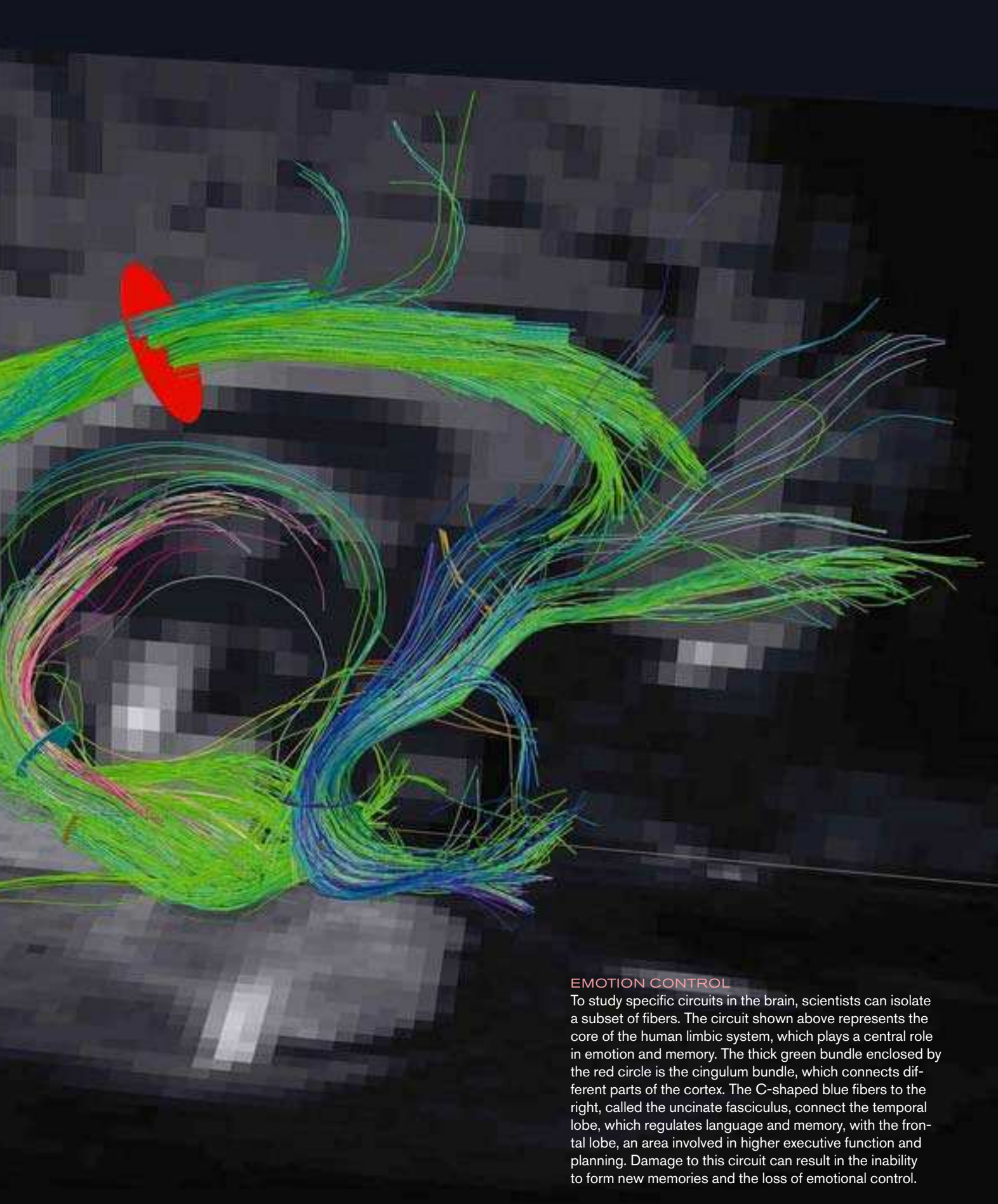
MAPPING DIFFUSION

Neural fibers in the brain are too tiny to image directly, so scientists map them by measuring the diffusion of water molecules along their length. The scientists first break the MRI image into "voxels," or three-dimensional pixels, and calculate the speed at which water is moving through each voxel in every direction. Those data are represented here as peanut-shaped blobs (first and second images below). From each shape, the researchers can infer the most likely path of the various nerve fibers (red and blue lines) passing through that spot. The result is a detailed diagram like that of the brain stem shown below (third image).







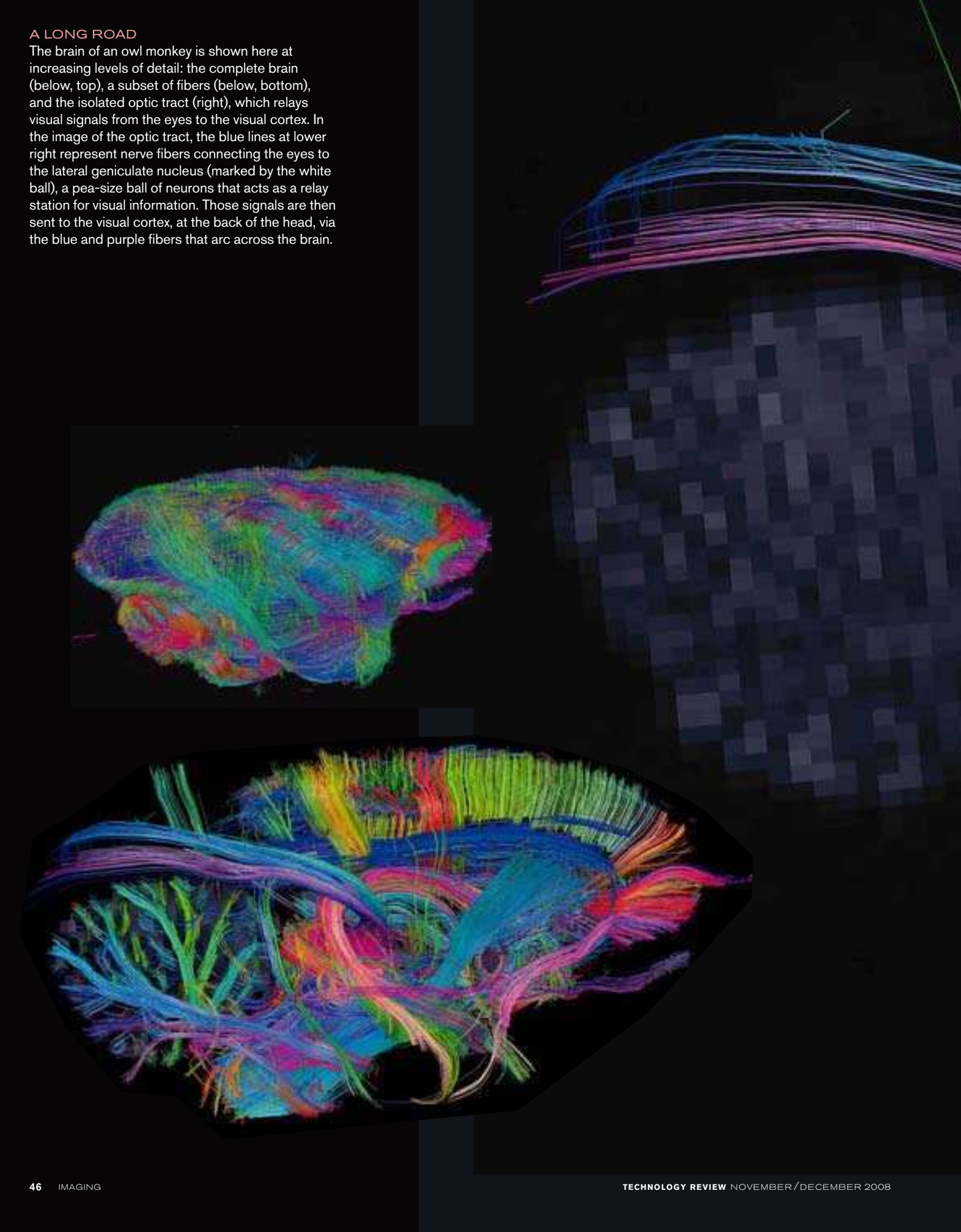


EMOTION CONTROL

To study specific circuits in the brain, scientists can isolate a subset of fibers. The circuit shown above represents the core of the human limbic system, which plays a central role in emotion and memory. The thick green bundle enclosed by the red circle is the cingulum bundle, which connects different parts of the cortex. The C-shaped blue fibers to the right, called the uncinate fasciculus, connect the temporal lobe, which regulates language and memory, with the frontal lobe, an area involved in higher executive function and planning. Damage to this circuit can result in the inability to form new memories and the loss of emotional control.

A LONG ROAD

The brain of an owl monkey is shown here at increasing levels of detail: the complete brain (below, top), a subset of fibers (below, bottom), and the isolated optic tract (right), which relays visual signals from the eyes to the visual cortex. In the image of the optic tract, the blue lines at lower right represent nerve fibers connecting the eyes to the lateral geniculate nucleus (marked by the white ball), a pea-size ball of neurons that acts as a relay station for visual information. Those signals are then sent to the visual cortex, at the back of the head, via the blue and purple fibers that arc across the brain.



Images by Van Wedeen, Ruopeng Wang, Jeremy Schmahmann, and Guangping Dai of the MGH Martinos Center for Biomedical Imaging in Boston, MA; Patric Hagmann of EPFL and CHUV, Lausanne, Switzerland; and Jon Kaas of Vanderbilt University, Nashville, TN.

www Explore these images in 3D using an interactive tool: **technologyreview.com/brain**

By DAVID TALBOT

Upwardly Mobile

AN INDIAN STARTUP THINKS THAT THE RIGHT SOFTWARE CAN MAKE CHEAP PHONES A FINANCIAL LIFELINE TO HUNDREDS OF MILLIONS.

In Bangalore's Avalahalli neighborhood, a bank account and microloans have transformed the life of 32-year-old Sabira Khanam. Her first loan, of 10,000 rupees (about $200), allowed her to experiment with a small-scale kerosene distributorship. A second, smaller infusion financed her sister's wedding. A third, of 20,000 rupees, launched a business sewing sequined saris for sale to local women. Khanam, who lives alone and has disabilities stemming from childhood polio, is now able to rent a large masonry house. And she got the cash to do this without resorting to local loan sharks, who charge 2 to 10 percent monthly interest for long-term loans—and much more for small, short-term loans.

But more than half of India's 1.1 billion people lack access to the kinds of financial services that made such a difference for Khanam. "In most of the developing world—and that means most of the world—the people that are 'unbanked,' or very badly banked, represent 70 percent of the population," says Michael Chu, a Harvard Business School lecturer and an expert on microfinance, which extends basic banking services to poor people who have not been served by the traditional financial system. "Literally, you are talking about 4 billion of the 6.5 billion people in the world. We are just beginning to penetrate that." And despite the well-understood potential of microlending to help lift people out of poverty, it currently reaches fewer than 200 million people worldwide. (A 2007 estimate put the figure as low as 133 million.) Microfinance "has been progressing at a very fast rate," Chu says. "But if you look at it in terms of how many people [enjoy the benefits], we are just beginning."

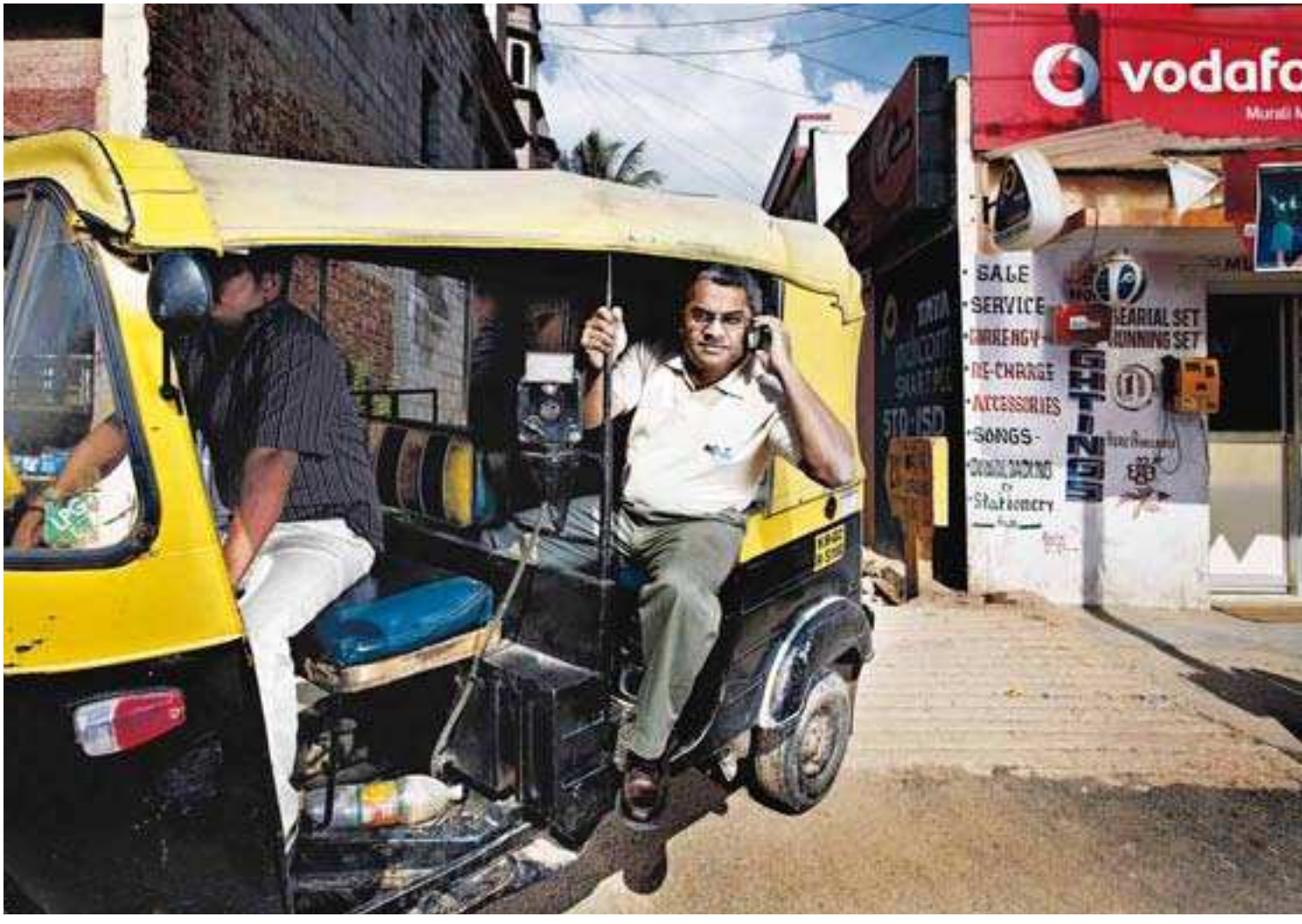
A peek at the administrative tasks associated with Khanam's loans helps explain why. A representative from Grameen Koota, the microfinance institution that lent to Khanam, must attend weekly meetings at her house to accept repayments. (Khanam leads a group that includes nine other borrowers, all of them women, who have financed everything from down payments on motorized rickshaws to materials for incense manufacture.) To service its 160,000 borrowers, Grameen Koota maintains a staff of 600, most of them loan officers from 52 branches who must attend 5,000 such meetings each week. Beyond the heavy workload, the risk of robbery, embezzlement, or fraud plagues the process. "Today, every one of my loan officers is carrying about 50,000 to 100,000 rupees to these meetings," says Suresh Krishna, Grameen Koota's managing director. "He is going 20 kilometers, collecting repayments, and bringing it back. We are carrying so much cash. We are prone to thefts, frauds, robberies, and misuses of this money. In one incident, one of my fellows was robbed; five people stopped him, showed knives, and snatched away 33,000 rupees."

While visiting Khanam's house and listening to her story over a glass of orange soda (and over the tinny strains of the prayer calls from the nearby mosque), I noticed that she owned a cell phone. It was a simple Nokia 1100, the low-end stalwart of developing-world communications; she purchased it last year after concluding that the business value justified the investment of 3,000 rupees (roughly the retail cost of six of her saris). Her prepaid plan allows outgoing calls for about half a rupee (less than two cents) per minute. One of her communication strategies is to note the phone number of an incoming call but not answer the phone. It's a common trick throughout the developing world; in this manner, people can convey mutually understood messages, such as "Let's meet."

Soon, the phone could transform how she deals with Grameen Koota. In one of a handful of such initiatives in India, a Bangalore startup called mChek is plunging into microfinance. Its software is already used by 500,000 people, who can use their mobile phones to pay their phone bills and purchase a limited number of goods and services, such as airline and movie tickets. Through a pilot project, as many as 5,000 borrowers will begin using the system

MICHAEL RUBENSTEIN

SARI SELLER Microloans have enabled Sabira Khanam to go into business in Bangalore. Technology that lets cell phones handle banking transactions could help microlending reach more people.



MONEY ON THE GO Sanjay Swamy, CEO of mChek, has made his Bangalore startup's payment software work on all cell phones and networks. It's one of several companies, including Obopay India, that are forging partnerships with lenders to provide mobile banking to the poor.

to manage their finances—tapping keys on their cell phones to access bank accounts and execute transfers, make payments to Grameen Koota, and possibly even do business with local merchants. Several borrowers should be able to share one phone. The new system could help Grameen Koota achieve its goal of roughly quadrupling its lending efforts by 2010. "All this will get eliminated," Krishna exclaims, pointing to photos of his loan officers poring over stacks of rupees. "All our transactions will be captured digitally. The back-office functions will become automated. It will become so much more efficient and save a lot of time. So we can add on more borrowers."

If this and similar efforts succeed, the concept could be extended to millions—even hundreds of millions—of Indians, giving them access to banking and credit for the first time. And India's national economy would stand to gain as well. Money that is electronically lodged in accounts earns interest for banks and account holders. Money sitting in wallets, or under mattresses, does not—and right now, 95 percent of financial transactions in India are conducted in cash. "You are talking about tens of billions of dollars in organized commerce on an annual basis," says Mohanjit Jolly, the executive director of the Indian office of the venture capital firm Draper Fisher Jurvetson, which has invested in mChek. "Treasury coffers will have a lot more money, and villagers will start earning interest on this money. Overall, the cost of capital will get reduced, liquidity will get increased, and you will see phenomenal changes in terms of what the villagers will be able to do. The bottom line: it's education, it's connectivity, it's improved quality of life ... [and] this mobile connectivity, this mobile transaction, is one of the key ingredients."

MOBILE LEAPFROG

More than 450 million Indians live below the poverty line—that is, on less than 25 rupees per day. Increasingly, though, these people are buying cell phones. By the end of August 2008, 305 million Indians had cell phones; the total grew by more than 9 million in

MICHAEL RUBENSTEIN

> If mobile banking services can be delivered to the millions of rural Indians now buying cell phones, "the cost of capital will get reduced, liquidity will get increased, and you will see phenomenal changes in terms of what villagers will be able to do."

August alone, making India the fastest-growing mobile market in the world and the second-largest after China. At this rate, observers say, India could have nearly 750 million cell-phone owners by the end of 2012. And most new subscribers are poor rural dwellers taking advantage of plunging costs for no-frills prepaid plans *(see "Phone Banking," p. 53)*. In signing up for cellular service, many of them are leapfrogging elements of the traditional infrastructure to which they have little or no access: landline phones, the Internet, the power grid.

All these new cell phones could deliver the benefits of no-frills banking and credit to the rural poor—something India's central bank, the Reserve Bank of India (RBI), has been pushing banks to do, since it could improve people's lives in myriad small ways. "A lot of poverty comes from having not even the tiniest amount of financial slack," says Antoinette Schoar, an associate professor of entrepreneurial finance at MIT's Sloan School of Management. "People who have no access to credit at all—like really small farmers—pay sometimes up to 10 percent per day. They literally take 100 rupees' worth of goods from a vendor and have to give back 110 rupees in the evening. If they have even a tiny shock one day—a tiny accident—and can't pay back the vendor, it is devastating." Credit can smooth out farmers' financial boom-and-bust cycles, she says, allowing more consistent access to food, medical care, and other necessities.

Until now, mChek's payment software has had fairly limited applications; its 500,000 registered users employ it mainly to top up prepaid accounts with Airtel, India's dominant mobile-phone company. (Most users are in India, but some are in Sri Lanka, the only other country where mChek now operates.) But in theory, the technology could be used for any financial transaction; entering a PIN and making a few clicks on the keypad shifts money from one place to another.

When I met with mChek CEO Sanjay Swamy in his third-floor office suite, overlooking a thoroughfare crawling with cars, motorcycles, and yellow motorized rickshaws, he was enthusiastic about the prospect that mChek could bring mobile banking to the masses. When Indians sign up for their first cell phones—a process that involves identity verification in a country that has no counterpart to the U.S. Social Security number—they could open a bank account simultaneously. Considering that Indians are signing up for 16 million new accounts monthly (the net increase is smaller because some accounts expire), "that's a half-million accounts per day, or about six accounts per second," Swamy told me. "By the time I finish this sentence, we lose the opportunity to bank a hundred people! That's how stunning the opportunity is. If they are sophisticated enough to learn how to use a cell phone, chances are they are sophisticated enough to use it for other applications." India's regulations, unlike those of some other countries, do not allow telecom companies to enroll people in bank accounts; only banks and nongovernmental organizations, including microfinance institutions like Grameen Koota, can do that. So for now, mChek hopes to form partnerships with such organizations.

To get some sense of the potential benefits for the Indian economy, consider just one type of transfer: the payment of phone bills themselves. Today, most Indian cell-phone users pay for service in advance, in cash; the average monthly expenditure is about 250 rupees. If only 10 percent of India's 305 million mobile-phone subscribers opened bank accounts and started paying just these bills electronically, more than 7,600 rupees, or $160 million, would exit the cash economy and enter the banking system every month.

And to grasp how ordinary people could benefit, consider the life of the average farmer in the Bangalore area. Typically, a farmer spends hours trekking into the city for a 4:00 A.M. auction to sell his goods. The auction concludes by 6:00 A.M., after which the farmer takes an IOU to a bank, waits for it to open, and collects his money. Then he returns home, risking theft on the way. "We looked at the model and said, What if the retailer could use mChek to pay farmers electronically, and the farmer would receive notification on his cell phone?" Swamy says. The company conducted a pilot project with Citibank and a Bangalore retailer that buys fresh produce; they learned that 85 percent of the farmers attending the auction already owned cell phones. And some reported that if they could accept payment electronically, not only would they save hours queuing at banks, but they might skip the journey altogether, sending a son or a hired laborer in their place.

DANCING WITH GORILLAS

Of course, mChek is not the first company with visions of using cell phones to bring banking to the world's poor. Ignacio Mas of the Consultative Group to Assist the Poor (CGAP), a microfinance think tank funded by 34 development organizations and housed at

the World Bank, traces the trend to 2001 in the Philippines, where a telecom company, Smart Communications, partnered with banks to provide financial services. The concept spread; by 2005 the South African startup Wizzit had launched a banking and payment platform for mobile phones. And in 2007 Kenya's leading telecom, Safaricom, launched the money transfer service M-Pesa.

Yet these efforts to graft developed-world banking onto developing-world mobile networks are not commensurate with the swelling popularity of the mobile phone itself. The larger story is one of pilot projects that petered out amid difficulties including cumbersome national regulations, unfriendly user interfaces, and an inability to make the right partnerships. "The reality of the field today is that the promise—which a lot of people understand is huge—is more in the conceptual stage," says Michael Chu. "The banking industry is very suspicious of the cell-phone industry, because they suspect that cell phones will make them obsolete. The cell-phone companies think the banks are like dinosaurs." But these players have to work together seamlessly for cell-phone-based banking to work.

Both mChek's technology and its business model are geared to avoiding such pitfalls, some observers say. The company got its start in 2006, when Draper Fisher Jurvetson spun it out from A Little World—a Mumbai company developing smart cards that the Indian government sought to use as national ID cards—and gave it $4 million in funding. From the beginning, mChek has emphasized security and usability. The software itself runs on any phone (even the years-old used phones sold at many storefronts), and the transactions use simple text messages that work on any network. Moreover, with two forms of encryption plus the usual PIN protection, the system is considered as secure as any card-swiping device in any retail outlet: mChek says it is the only mobile payment platform to have won certification from Visa. And the company isn't locked into an exclusive partnership with any one bank or mobile carrier, so it's flexible and able to grow. "What's great about what they are doing is that they are working with all of the [mobile carriers] and banks," says Crystal Hutter, a manager of investments at Omidyar Network, the philanthropic investment firm established by eBay founder Pierre Omidyar, which is active in microfinance. "They are not locking themselves into one operator or one bank. Having the ability to work interoperably is huge."

Serious growth became more likely in August, when Airtel decided to incorporate the mChek platform directly into the SIM card—the device inside a mobile phone that identifies the user and phone number—on all four million phones it ships monthly to new customers. This means phone owners won't have to seek out and download mChek's software. Airtel is marketing the feature heavily as a way to pay phone bills, in part because it pays mChek less for each transaction than it pays the 800,000 retailers who now accept cash payments (mostly prepaid top-ups) on its behalf. For mChek, then, the task now is to forge more such partnerships and navigate a shifting regulatory environment. Draper Fisher Jurvetson's Jolly says that mChek's achievements thus far are unique in India. "I often talk about [mChek] as a company that is dancing with gorillas or behemoths," says Jolly. "You have the banking sector on one side and the [telecom companies] on the other side, and then you've got the MasterCard and Visa folks, and finally the regulatory oversight bodies like the RBI. Trying to corral all of them, for a startup, is next to impossible. What mChek has been able to accomplish in India has never been done before."

The company does face some emerging local competition. In Bangalore, JiGrahak Mobility Solutions has developed a popular bill-paying and banking platform, but it's sticking to the upper end of the market; its service requires the Internet connections available on higher-end phones. In Delhi, Eko India Financial Services is partnering with a local bank to bring no-frills bank accounts to the rural poor in a pilot project limited to 5,000 people. And Obopay India—the Indian branch of a U.S. firm—is working on developing a mobile microfinance platform in partnership with Grameen Solutions, one of the organizations created by the Bangladeshi microfinancier Muhammad Yunus, winner of the 2006 Nobel Peace Prize. (It is not connected with Grameen Koota in Bangalore: grameen means "rural" or "of the village.") Obopay's initiative, called "Bank a Billion," was scheduled for a rollout in Mumbai and Bangladesh by early November, says Vijay Balakrishnan, chief marketing officer for Obopay India, which hopes to enroll a million people in those two regions within 18 months. In Obopay's scheme, the purchase price of a cell phone would be built into a Grameen microloan; bill-paying software would be incorporated into the SIM card; and the borrower would open a no-frills bank account.

CASH AND COWS

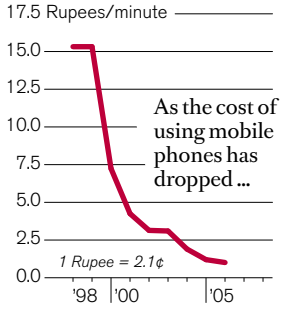
The difficulty with such efforts is that it's not clear how hundreds of millions of poor rural people doing mobile banking would actually deposit and withdraw cash, even if they used their phones for transfers. No nation has yet convinced its citizens to forsake cash-stuffed wallets and convenient ATMs. Sabira Khanam, for example, sells her saris for cash. And she makes cash deposits in a conventional bank account (though from there, she will be able to receive and repay microloans electronically under the Grameen Koota/mChek project). "Today, cell-phone companies by themselves cannot provide the things that banks provide," says Harvard's Chu. "At the end of the day, if this is to be an effective platform, you have to have physical delivery or access to the funds."

WWW See David Talbot's video reports from Bangalore: **technologyreview.com/mchek**

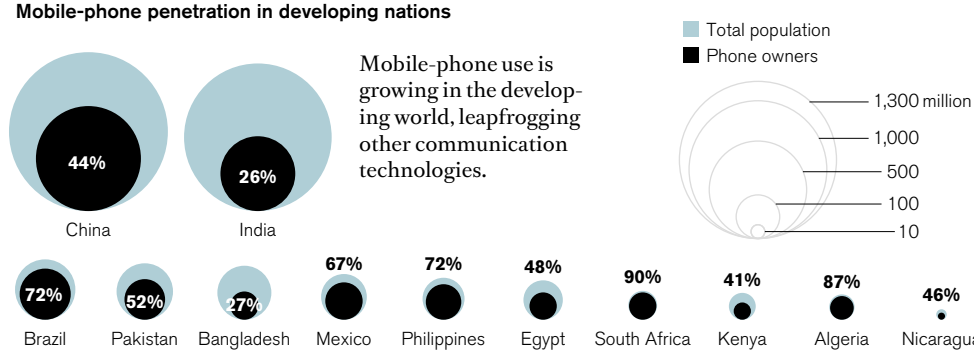
PHONE BANKING

Around the world, and particularly in India, more and more people are using cell phones as costs fall (top and left). These phones could be used to extend loans and savings accounts to the poor families who now lack access to the financial system (bottom).

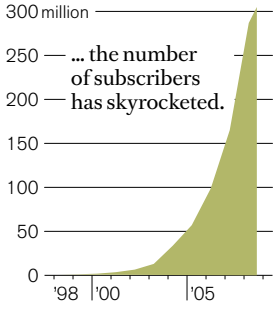
Mobile charges in India



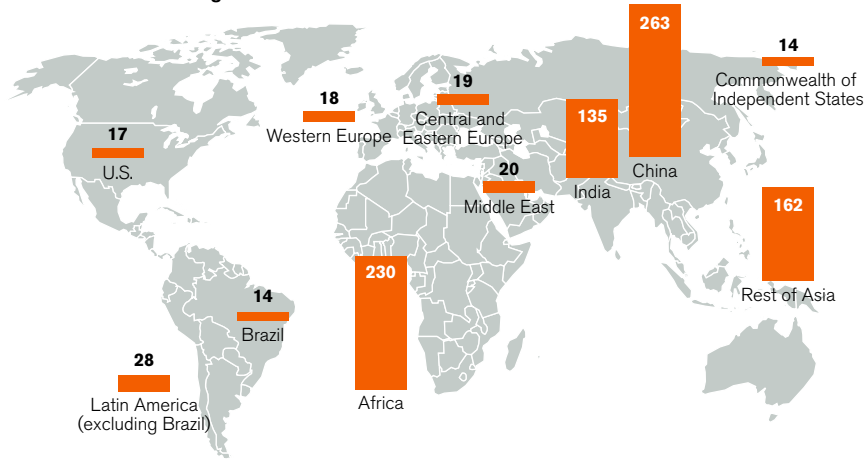
Mobile-phone penetration in developing nations



Mobile subscribers in India
through August 2008



Millions of households lacking bank accounts



Sources: Telecom Regulatory Authority of India (costs and subscribers); GSMA's Wireless Intelligence (mobile penetration); Boston Consulting Group (excluded households)

CHARTS BY TOMMY McCALL

In India, some existing programs could help bridge the gap. Prodded by government mandates, state-owned banks such as Punjab National Bank, State Bank of India, and Corporation Bank have established outreach programs in recent years. An array of branchless-banking efforts—stand-alone kiosks, portable terminals manned by village representatives, and banking services delivered through a Kinko's-like retail franchise run by a firm called Comat—have appeared in some of India's 638,000 villages.

One such effort has taken hold in Kasaghatta, a village about 70 kilometers north of Bangalore. Reached by a few kilometers of bumpy dirt road, Kasaghatta does not appear on national maps. Extended families share concrete or thatched houses; women in brightly colored saris scrub pots and lead cows down red-earth alleys; men haul steel buckets of fresh milk to waiting delivery trucks; roosters skitter about. The rocky hills that characterize southern India's Deccan Plateau dot the horizon.

If you need anything in Kasaghatta, the person to see is Muniyamma Ramanjanappa. A calm and kindly grandmother in her 40s, she manages the village school and serves as its teacher for the primary grades. She's also the government's point of contact on health programs for women and children. Government-issued supplies and medicines, as well as financial assistance to local mothers, are routed through her. She frequently travels seven kilometers by bus to the nearest branch of the state-run Corporation Bank, which disburses government benefits. Through her relationship with the tellers, she has become the bank's "correspondent" to Kasaghatta. The bank issued her a machine—manufactured by the Bangalore startup Integra Microsystems—that in 2007 brought banking to the village for the first time. Villagers

BRANCHLESS BANKING Villagers in Kasaghatta, India, make cash deposits with a local bank representative, who confirms their identities with a fingerprint reader and a smart card. Such outreach efforts could complement cell-phone transactions by providing new ways to deal with cash.

who visit Muniyamma can now use smart cards and thumbprint authentication to deposit and withdraw cash. Muniyamma keeps the cash in a strongbox, reconciles accounts via a wireless connection to the bank (established over her cell phone), and gives out printed receipts for each transaction.

On the day I visited, Muniyamma padded barefoot around her tidy one-room concrete home, where immaculate steel cookware was stacked in the kitchen area. A silver wedding ring encircled the second toe of her left foot; studs adorned both ears and her right nostril; a mint-green sari swathed most of the rest of her. Before long, Jayalakshmamma Doddarasaiah, a 22-year-old mother of two, arrived carrying her 17-month-old son, Mahesha. Jayalakshmamma wanted to deposit 100 rupees from a recent sale of ragi, a local crop similar to millet. She was in a hurry, as it was almost time to milk the cows in her extended family's concrete-and-thatch compound two alleys over. Jayalakshmamma slid her smart card into a plastic slot on the side of Muniyamma's white metal machine and, after some prompting from the audio interface, placed her left thumb on the reader. The ragi harvest had left her fingers cut and callused, so the machine was unable to recognize her. But other villagers who stopped by had no problems, and the technology is clearly widening their opportunities. For example, a 55-year-old village man named Karehanumaiah was able to deposit 150 rupees. Until early 2008, he'd never had a bank account or access to formal credit. Borrowing 1,800 rupees from an informal lender to buy a goat would have cost him as much as 10 percent monthly interest. Now he has a savings account and can borrow from his bank.

Such approaches have their critics; Swamy is one. He says that India could, in fact, become utterly cashless; a man like Karehanumaiah could be paid for his farm labor electronically and buy goods and services the same way. Given that many areas of India have no banking infrastructure at all, he argues, it makes no sense to try to build kiosks and machines. "Those are nonscalable models and very labor-intensive models," Swamy says. "If he can do it in his village, he can do it in his pocket [with his cell phone]. That is our perspective." Still, most experts say a wholesale changeover to electronic transactions is unrealistic, and that mobile banking will require some connection to the cash economy.

Either way, the technology is there; the issue now is creating the environment necessary to cultivate it. "First, it will take changes in regulation," says CGAP's Ignacio Mas. "Second, it will take a mind shift by the banks to see opportunities where they haven't before. And it will take partnerships: how will the [telecom companies] and banks come together with companies like mChek and other vendors who can bring together the [retail] agents?"

Nobody has specifically proposed using cell phones for banking in Kasaghatta. But it is plain to see that in the village, all the elements are in place. Not long after watching Jayalakshmamma's failed effort to deposit 100 rupees, I visited her home. The scene was one of bare-bones rural living; her parents sat on a floor of packed dirt, holding her daughter. Two cows munched grass nearby. Reaching the interior of the one-room concrete hut required passing through a thatched enclosure housing more cows. But it turned out that Jayalakshmamma's husband, like Sabira Khanam, owns a cell phone. I asked Muniyamma how many people had bank accounts in the village, and the answer came back: 190 of the 700 residents. Then I asked how many owned cell phones. The number was 300, and counting. TR

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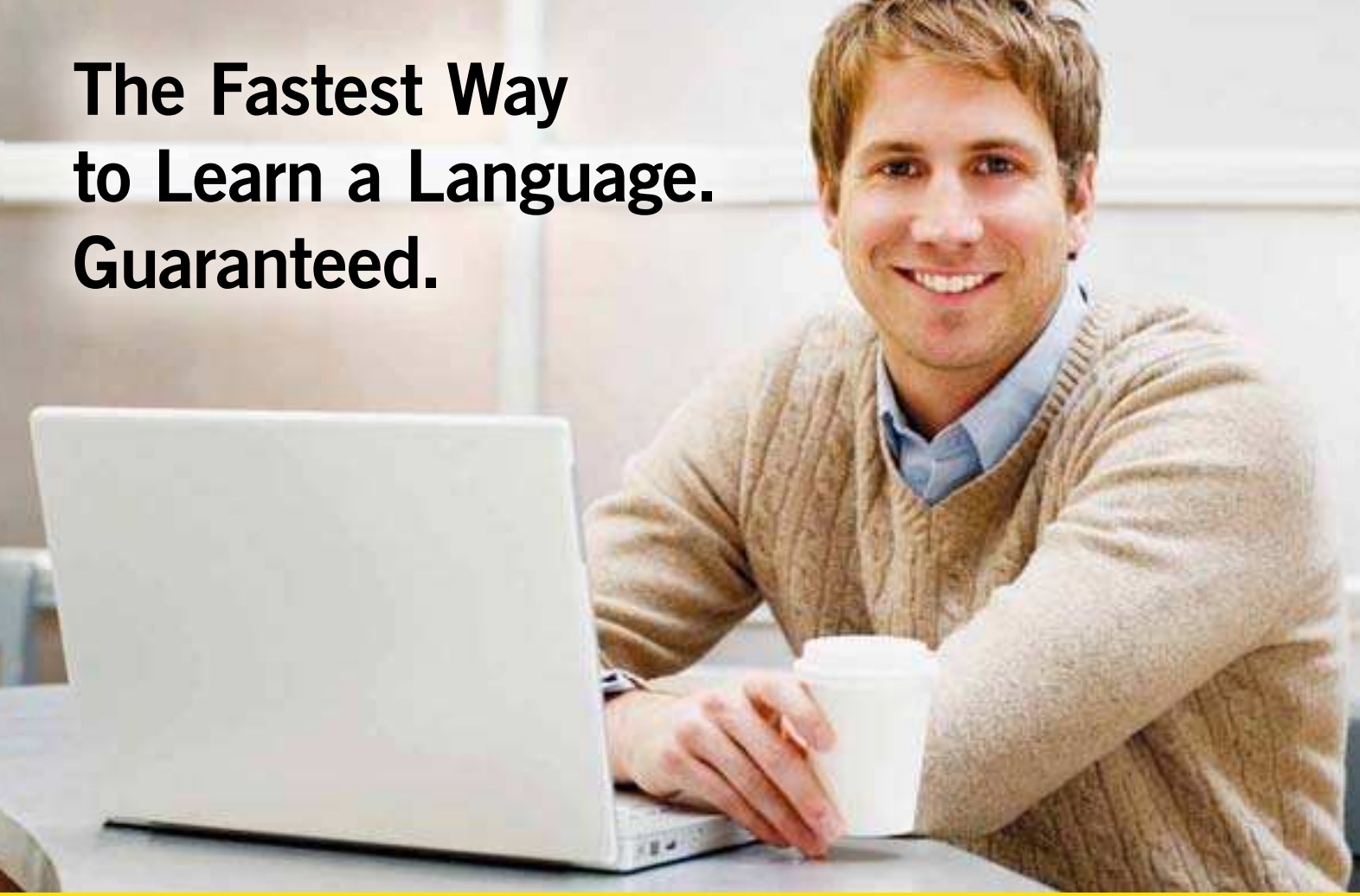

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WITH CATALYSTS CREATED BY AN MIT CHEMIST, SUNLIGHT CAN TURN WATER INTO HYDROGEN GAS. IF THE PROCESS CAN SCALE UP, IT COULD MAKE SOLAR POWER A DOMINANT SOURCE OF ENERGY.

By KEVIN BULLIS

"I'm going to show you something I haven't showed anybody yet," said Daniel Nocera, a professor of chemistry at MIT, speaking this May to an auditorium filled with scientists and U.S. government energy officials. He asked the house manager to lower the lights. Then he started a video. "Can you see that?" he asked excitedly, pointing to the bubbles rising from a strip of material immersed in water. "Oxygen is pouring off of this electrode." Then he added, somewhat cryptically, "This is the future. We've got the leaf."

What Nocera was demonstrating was a reaction that generates oxygen from water much as green plants do during photosynthesis—an achievement that could have profound implications for the energy debate. Carried out with the help of a catalyst he developed, the reaction is the first and most difficult step in splitting water to make hydrogen gas. And efficiently generating hydrogen from water, Nocera believes, will help surmount one of the main obstacles preventing solar power from becoming a dominant source of electricity: there's no cost-effective way to store the energy collected by solar panels so that it can be used at night or during cloudy days.

Solar power has a unique potential to generate vast amounts of clean energy that doesn't contribute to global warming. But without a cheap means to store this energy, solar power can't replace fossil fuels on a large scale. In Nocera's scenario, sunlight would split water to produce versatile, easy-to-store hydrogen fuel that could later be burned in an internal-combustion generator or recombined with oxygen in a fuel cell. Even more ambitious, the reaction could be used to split seawater; in that case, running the hydrogen through a fuel cell would yield fresh water as well as electricity.

Storing energy from the sun by mimicking photosynthesis is something scientists have been trying to do since the early 1970s. In particular, they have tried to replicate the way green plants break down water. Chemists, of course, can already split water. But the process has required high temperatures, harsh alkaline solutions, or rare and expensive catalysts such as platinum. What Nocera has devised is an inexpensive catalyst that produces oxygen from water at room temperature and without caustic chemicals—the same benign conditions found in plants. Several other promising catalysts, including another that Nocera developed, could be used to complete the process and produce hydrogen gas.

Nocera sees two ways to take advantage of his breakthrough. In the first, a conventional solar panel would capture sunlight to produce electricity; in turn, that electricity would power a device called an electrolyzer, which would use his catalysts to split water. The second approach would employ a system that more closely mimics the structure of a leaf. The catalysts would be deployed side by side with special dye molecules designed to absorb sunlight;

Photograph by CHRISTOPHER HARTING

LEAF ENVY MIT chemist Daniel Nocera has mimicked the step in photosynthesis in which green plants split water.

the energy captured by the dyes would drive the water-splitting reaction. Either way, solar energy would be converted into hydrogen fuel that could be easily stored and used at night—or whenever it's needed.

Nocera's audacious claims for the importance of his advance are the kind that academic chemists are usually loath to make in front of their peers. Indeed, a number of experts have questioned how well his system can be scaled up and how economical it will be. But Nocera shows no signs of backing down. "With this discovery, I totally change the dialogue," he told the audience in May. "All of the old arguments go out the window."

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THE DARK SIDE OF SOLAR

Sunlight is the world's largest potential source of renewable energy, but that potential could easily go unrealized. Not only do solar panels not work at night, but daytime production waxes and wanes as clouds pass overhead. That's why today most solar panels—both those in solar farms built by utilities and those mounted on the roofs of houses and businesses—are connected to the electrical grid. During sunny days, when solar panels are operating at peak capacity, homeowners and companies can sell their excess power to utilities. But they generally have to rely on the grid at night, or when clouds shade the panels.

This system works only because solar power makes such a tiny contribution to overall electricity production: it meets a small fraction of 1 percent of total demand in the United States. As the contribution of solar power grows, its unreliability will become an increasingly serious problem.

If solar power grows enough to provide as little as 10 percent of total electricity, utilities will need to decide what to do when clouds move in during times of peak demand, says Ryan Wiser, a research scientist who studies electricity markets at Lawrence Berkeley National Laboratory in Berkeley, CA. Either utilities will need to operate extra natural-gas plants that can quickly ramp up to compensate for the lost power, or they'll need to invest in energy storage. The first option is currently cheaper, Wiser says: "Electrical storage is just too expensive."

But if we count on solar energy for more than about 20 percent of total electricity, he says, it will start to contribute to what's called base load power, the amount of power necessary to meet minimum demand. And base load power (which is now supplied mostly by coal-fired plants) must be provided at a relatively constant rate. Solar energy can't be harnessed for this purpose unless it can be stored on a large scale for use 24 hours a day, in good weather and bad.

In short, for solar to become a primary source of electricity, vast amounts of affordable storage will be needed. And today's options for storing electricity just aren't practical on a large enough scale, says Nathan Lewis, a professor of chemistry at Caltech. Take one of the least expensive methods: using electricity to pump water uphill and then running the water through a turbine to generate electricity later on. One kilogram of water pumped up 100 meters stores about a kilojoule of energy. In comparison, a kilogram of gasoline stores about 45,000 kilojoules. Storing enough energy this way would require massive dams and huge reservoirs that would be emptied and filled every day. And try finding enough water for that in places such as Arizona and Nevada, where sunlight is particularly abundant.

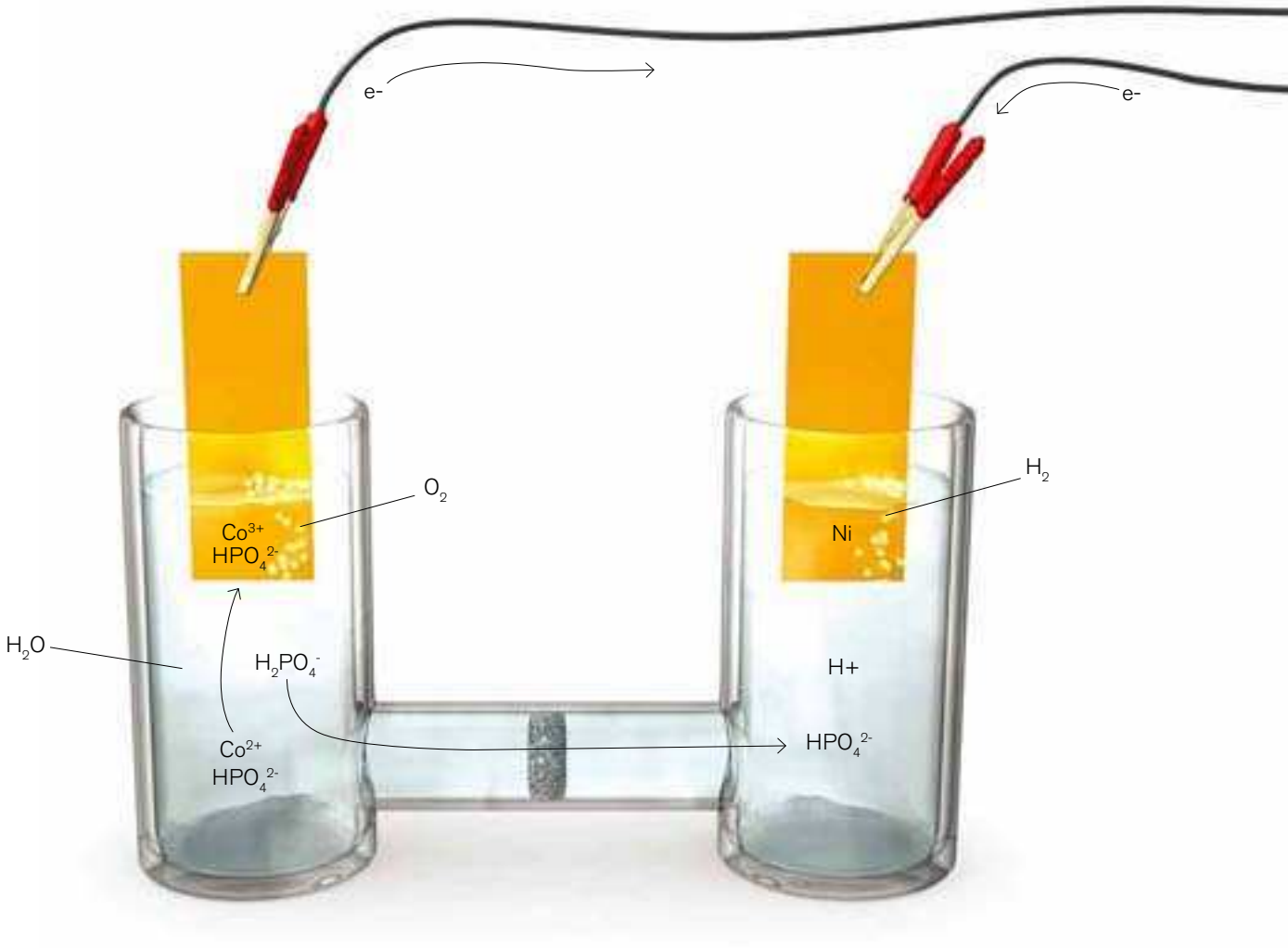
Batteries, meanwhile, are expensive: they could add $10,000 to the cost of a typical home solar system. And although they're improving, they still store far less energy than fuels such as gasoline and hydrogen store in the form of chemical bonds. The best batteries store about 300 watt-hours of energy per kilogram, Lewis says, while gasoline stores 13,000 watt-hours per kilogram. "The numbers make it obvious that chemical fuels are the only energy-dense way to obtain massive energy storage," Lewis says. Of those fuels, not only is hydrogen potentially cleaner than gasoline, but by weight it stores much more energy—about three times as much, though it takes up more space because it's a gas.

The challenge lies in using energy from the sun to make such fuels cheaply and efficiently. This is where Nocera's efforts to mimic photosynthesis come in.

IMITATING PLANTS

In real photosynthesis, green plants use chlorophyll to capture energy from sunlight and then use that energy to drive a series of complex chemical reactions that turn water and carbon dioxide into energy-rich carbohydrates such as starch and sugar. But what primarily interests many researchers is an early step in the process, in which a combination of proteins and inorganic catalysts helps break water efficiently into oxygen and hydrogen ions.

The field of artificial photosynthesis got off to a quick start. In the early 1970s, a graduate student at the University of Tokyo,



BRYAN CHRISTIE

PHOTOSYNTHESIS IN A BEAKER

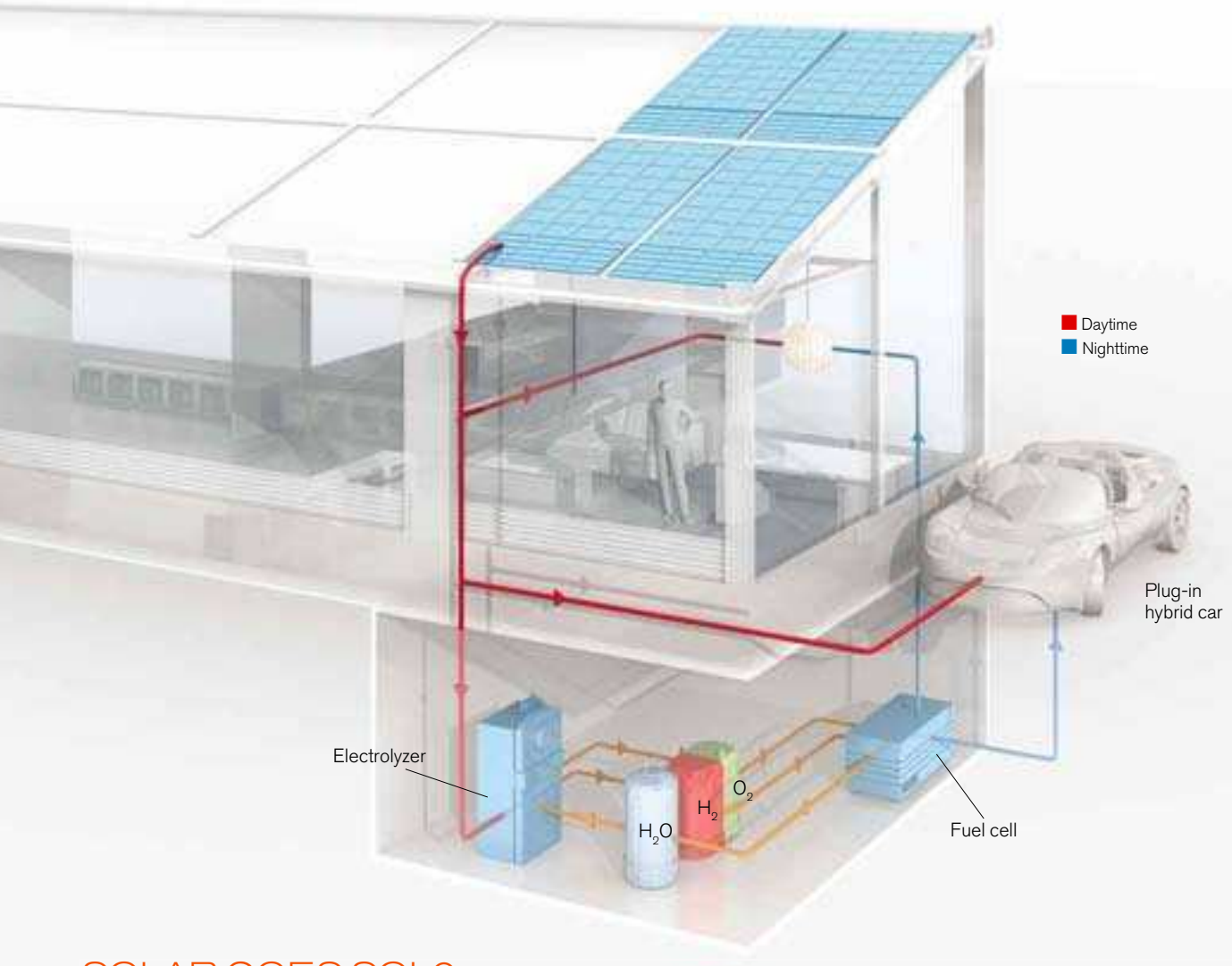
In an experimental setup that duplicates the benign conditions found in photosynthetic plants, Daniel Nocera has demonstrated an easy and potentially cheap way to produce hydrogen gas. When a voltage is applied, cobalt and phosphate in solution (left) accumulate on an electrode to form a catalyst, which releases oxygen gas from the water as electrons flow out through the electrode. Hydrogen ions flow through a membrane; on the other side, hydrogen gas is produced by a nickel metal catalyst (Nocera has also used a platinum catalyst).

Akira Fujishima, and his thesis advisor, Kenichi Honda, showed that electrodes made from titanium dioxide—a component of white paint—would slowly split water when exposed to light from a bright, 500-watt xenon lamp. The finding established that light could be used to split water outside of plants. In 1974, Thomas Meyer, a professor of chemistry at the University of North Carolina, Chapel Hill, showed that a ruthenium-based dye, when exposed to light, underwent chemical changes that gave it the potential to oxidize water, or pull electrons from it—the key first step in water splitting.

Ultimately, neither technique proved practical. The titanium dioxide couldn't absorb enough sunlight, and the light-induced chemical state in Meyer's dye was too transient to be useful. But the advances stimulated the imaginations of scientists. "You could look ahead and see where to go and, at least in principle, put the pieces together," Meyer says.

Over the next few decades, scientists studied the structures and materials in plants that absorb sunlight and store its energy. They found that plants carefully choreograph the movement of water molecules, electrons, and hydrogen ions—that is, protons. But much about the precise mechanisms involved remained unknown. Then, in 2004, researchers at Imperial College London identified the structure of a group of proteins and metals that is crucial for freeing oxygen from water in plants. They showed that the heart of this catalytic complex was a collection of proteins, oxygen atoms, and manganese and calcium ions that interact in specific ways.

"As soon as we saw this, we could start designing systems," says Nocera, who had been trying to fully understand the chemistry behind photosynthesis since 1984. Reading this "road map," he says, his group set out to manage protons and electrons somewhat the way plants do—but using only inorganic materials, which are more robust and stable than proteins.



SOLAR GOES SOLO

Artificial photosynthesis could provide a practical way to store energy produced by solar power, freeing people's homes from the electrical grid. In this scheme, electricity from solar panels powers an electrolyzer, which breaks water into hydrogen and oxygen. The hydrogen is stored; at night or on cloudy days, it is fed into a fuel cell to produce electricity for lights, appliances, and even electric cars. On sunny days, some of the solar power is used directly, bypassing the hydrogen production step.

Initially, Nocera didn't tackle the biggest challenge, pulling oxygen out from water. Rather, "to get our training wheels," he began with the reverse reaction: combining oxygen with protons and electrons to form water. He found that certain complex compounds based on cobalt were good catalysts for this reaction. So when it came time to try splitting water, he decided to use similar cobalt compounds.

Nocera knew that working with these compounds in water could be a problem, since cobalt can dissolve. Not surprisingly, he says, "within days we realized that cobalt was falling out of this elaborate compound that we made." With his initial attempts foiled, he decided to take a different approach. Instead of using a complex compound, he tested the catalytic activity of dissolved cobalt, with some phosphate added to the water to help the reaction. "We said, let's forget all the elaborate stuff and just use cobalt directly," he says.

The experiment worked better than Nocera and his colleagues had expected. When a current was applied to an electrode immersed in the solution, cobalt and phosphate accumulated on it in a thin film, and a dense layer of bubbles started forming in just a few minutes. Further tests confirmed that the bubbles were oxygen released by splitting the water. "Here's the luck," Nocera says. "There was no reason for us to expect that just plain cobalt with phosphate, versus cobalt being tied up in one of our complexes,

BRYAN CHRISTIE

would work this well. I couldn't have predicted it. The stuff that was falling out of the compounds turned out to be what we needed.

"Now we want to understand it," he continues. "I want to know why the hell cobalt in this thin film is so active. I may be able to improve it or use a different metal that's better." At the same time, he wants to start working with engineers to optimize the process and make an efficient water-splitting cell, one that incorporates catalysts for generating both oxygen and hydrogen. "We were really interested in the basic science. Can we make a catalyst that works efficiently under the conditions of photosynthesis?" he says. "The answer now is yes, we can do that. Now we've really got to get to the technology of designing a cell."

CATALYZING A DEBATE

Nocera's discovery has garnered a lot of attention, and not all of it has been flattering. Many chemists find his claims overstated; they don't dispute his findings, but they doubt that they will have the consequences he imagines. "The claim that this is the answer for artificial photosynthesis is crazy," says Thomas Meyer, who has been a mentor to Nocera. He says that while Nocera's catalysts "could prove technologically important," the advance is "a research finding," and there's "no guarantee that it can be scaled up or even made practical."

Many critics' objections revolve around the inability of Nocera's lab setup to split water nearly as rapidly as commercial electrolyzers do. The faster the system, the smaller a commercial unit that produced a given amount of hydrogen and oxygen would be. And smaller systems, in general, are cheaper.

The way to compare different catalysts is to look at their "current density"—that is, electrical current per square centimeter—when they're at their most efficient. The higher the current, the faster the catalyst can produce oxygen. Nocera reported results of 1 milliamp per square centimeter, although he says he's achieved 10 milliamps since then. Commercial electrolyzers typically run at about 1,000 milliamps per square centimeter. "At least what he's published so far would never work for a commercial electrolyzer, where the current density is 800 times to 2,000 times greater," says John Turner, a research fellow at the National Renewable Energy Laboratory in Golden, CO.

Other experts question the whole principle of converting sunlight into electricity, then into a chemical fuel, and then back into electricity again. They suggest that while batteries store far less energy than chemical fuels, they are nevertheless far more efficient, because using electricity to make fuels and then using the fuels to generate electricity wastes energy at every step. It would be better, they say, to focus on improving battery technology or other similar forms of electrical storage, rather than on developing water splitters and fuel cells. As Ryan Wiser puts it, "Electrolysis is [currently] inefficient, so why would you do it?"

THE ARTIFICIAL LEAF

Michael Grätzel, however, may have a clever way to turn Nocera's discovery to practical use. A professor of chemistry and chemical engineering at the École Polytechnique Fédérale in Lausanne, Switzerland, he was one of the first people Nocera told about his new catalyst. "He was so excited," Grätzel says. "He took me to a restaurant and bought a tremendously expensive bottle of wine."

In 1991, Grätzel invented a promising new type of solar cell. It uses a dye containing ruthenium, which acts much like the chlorophyll in a plant, absorbing light and releasing electrons. In Grätzel's solar cell, however, the electrons don't set off a water-splitting reaction. Instead, they're collected by a film of titanium dioxide and directed through an external circuit, generating electricity. Grätzel now thinks that he can integrate his solar cell and Nocera's catalyst into a single device that captures the energy from sunlight and uses it to split water.

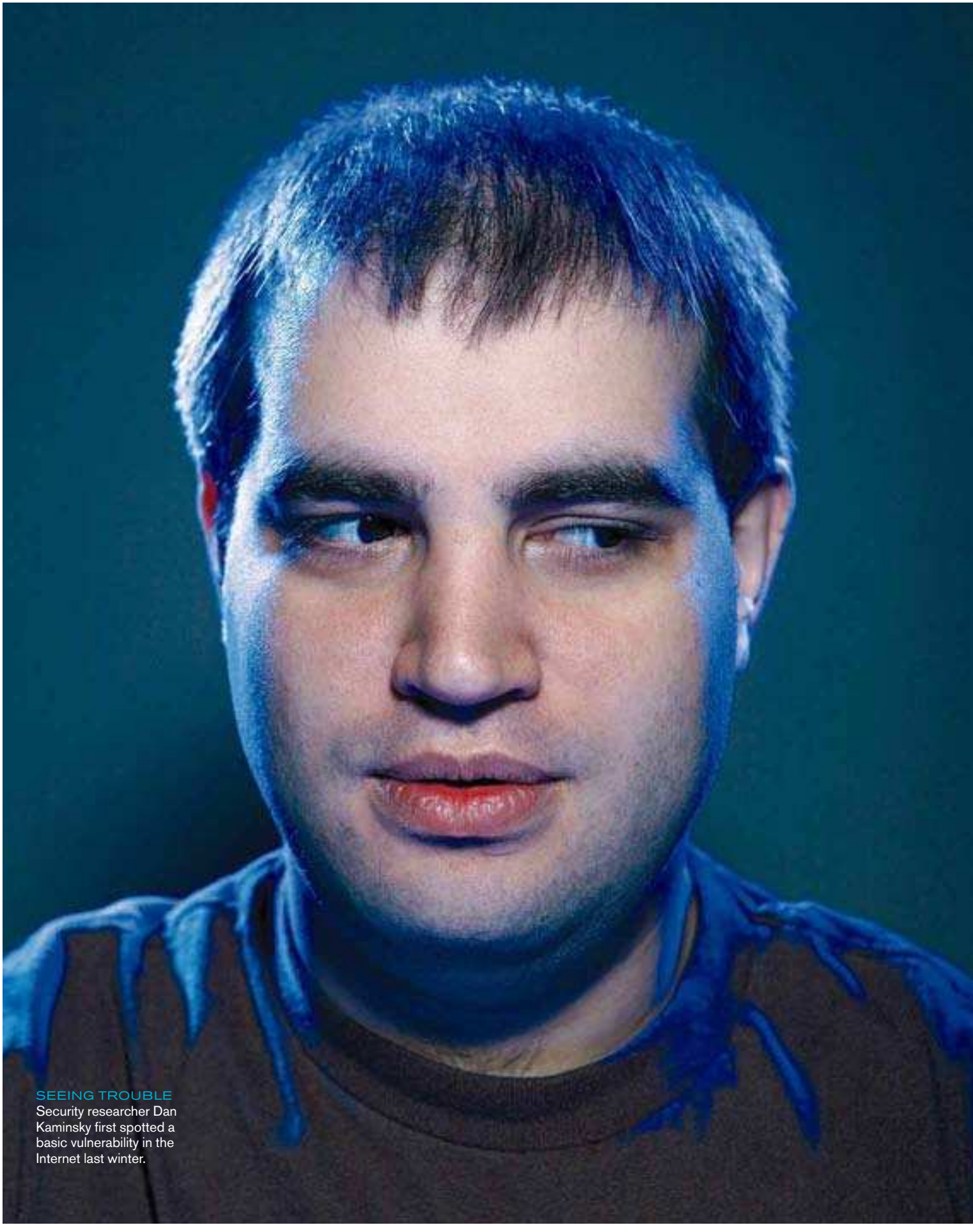
If he's right, it would be a significant step toward making a device that, in many ways, truly resembles a leaf. The idea is that Grätzel's dye would take the place of the electrode on which the catalyst forms in Nocera's system. The dye itself, when exposed to light, can generate the voltage needed to assemble the catalyst. "The dye acts like a molecular wire that conducts charges away," Grätzel says. The catalyst then assembles where it's needed, right on the dye. Once the catalyst is formed, the sunlight absorbed by the dye drives the reactions that split water. Grätzel says that the device could be more efficient and cheaper than using a separate solar panel and electrolyzer.

Another possibility that Nocera is investigating is whether his catalyst can be used to split seawater. In initial tests, it performs well in the presence of salt, and he is now testing it to see how it handles other compounds found in the sea. If it works, Nocera's system could address more than just the energy crisis; it could help solve the world's growing shortage of fresh water as well.

Artificial leaves and fuel-producing desalination systems might sound like grandiose promises. But to many scientists, such possibilities seem maddeningly close; chemists seeking new energy technologies have been taunted for decades by the fact that plants easily use sunlight to turn abundant materials into energy-rich molecules. "We see it going on all around us, but it's something we can't really do," says Paul Alivisatos, a professor of chemistry and materials science at the University of California, Berkeley, who is leading an effort at Lawrence Berkeley National Laboratory to imitate photosynthesis by chemical means.

But soon, using nature's own blueprint, human beings could be using the sun "to make fuels from a glass of water," as Nocera puts it. That idea has an elegance that any chemist can appreciate—and possibilities that everyone should find hopeful. TR

KEVIN BULLIS IS *TECHNOLOGY REVIEW*'S ENERGY EDITOR.



SEEING TROUBLE
Security researcher Dan Kaminsky first spotted a basic vulnerability in the Internet last winter.

The Flaw at the Heart of the Internet

DAN KAMINSKY DISCOVERED A FUNDAMENTAL SECURITY PROBLEM IN THE INTERNET AND GOT PEOPLE TO CARE IN TIME TO FIX IT. IT'S A DRAMATIC STORY WITH A HAPPY ENDING ... BUT WE WERE LUCKY THIS TIME.

By ERICA NAONE

Dan Kaminsky, uncharacteristically, was not looking for bugs earlier this year when he happened upon a flaw at the core of the Internet. The security researcher was using his knowledge of Internet infrastructure to come up with a better way to stream videos to users. Kaminsky's expertise is in the Internet's domain name system (DNS), the protocol responsible for matching websites' URLs with the numeric addresses of the servers that host them. The same content can be hosted by multiple servers with several addresses, and Kaminsky thought he had a great trick for directing users to the servers best able to handle their requests at any given moment.

Normally, DNS is reliable but not nimble. When a computer—say, a server that helps direct traffic across Comcast's network—requests the numerical address associated with a given URL, it stores the answer for a period of time known as "time to live," which can be anywhere from seconds to days. This helps to reduce the number of requests the server makes. Kaminsky's idea was to bypass the time to live, allowing the server to get a fresh answer every time it wanted to know a site's address. Consequently, traffic on Comcast's network would be sent to the optimal address at every moment, rather than to whatever address had already been stored. Kaminsky was sure that the strategy could significantly speed up content distribution.

It was only later, after talking casually about the idea with a friend, that Kaminsky realized his "trick" could completely break the security of the domain name system and, therefore, of the Internet itself. The time to live, it turns out, was at the core of DNS security; being able to bypass it allowed for a wide variety of attacks. Kaminsky wrote a little code to make sure the situation was as bad as he thought it was. "Once I saw it work, my stomach dropped," he says. "I thought, 'What the heck am I going to do about this? This affects everything.'"

Kaminsky's technique could be used to direct Web surfers to any Web page an attacker chose. The most obvious use is to send people to phishing sites (websites designed to trick people into entering banking passwords and other personal information, allowing an attacker to steal their identities) or other fake versions of Web pages. But the danger is even worse: protocols such as those used to deliver e-mail or for secure communications over the Internet ultimately rely on DNS. A creative attacker could use Kaminsky's technique to intercept sensitive e-mail, or to create forged versions of the certificates that ensure secure transactions between users and banking websites. "Every day I find another domino," Kaminsky says. "Another thing falls over if DNS is bad. ... I mean, literally, you look around and see anything that's using a network—*anything* that's using a network—and it's probably using DNS."

Kaminsky called Paul Vixie, president of the Internet Systems Consortium, a nonprofit corporation that supports several aspects of Internet infrastructure, including the software most commonly used in the domain name system. "Usually, if somebody wants to report a problem, you expect that it's going to take a fair amount of time for them to explain it—maybe a whiteboard, maybe a Word document or two," Vixie says. "In this case, it took 20 seconds for him to explain the problem, and another 20 seconds for him to answer my objections. After that, I said, 'Dan, I am speaking to you over an unsecure cell phone. Please do not ever say to anyone what you just said to me over an unsecure cell phone again.'"

Perhaps most frightening was that because the vulnerability was not located in any particular hardware or software but in the design of the DNS protocol itself, it wasn't clear how to fix it. In secret, Kaminsky and Vixie gathered together some of the top DNS experts in the world: people from the U.S. government and

Photograph by JOHN KEATLEY

high-level engineers from the major manufacturers of DNS software and hardware—companies that include Cisco and Microsoft. They arranged a meeting in March at Microsoft's campus in Redmond, WA. The arrangements were so secretive and rushed, Kaminsky says, that "there were people on jets to Microsoft who didn't even know what the bug was."

Once in Redmond, the group tried to determine the extent of the flaw and sort out a possible fix. They settled on a stopgap measure that fixed most problems, would be relatively easy to deploy, and would mask the exact nature of the flaw. Because attackers commonly identify security holes by reverse-engineering patches intended to fix them, the group decided that all its members had to release the patch simultaneously (the release date would turn out to be July 8). Kaminsky also asked security researchers not to publicly speculate on the details of the flaw for 30 days after the release of the patch, in an attempt to give companies enough time to secure their servers.

On August 6, at the Black Hat conference, the annual gathering of the world's Internet security experts, Kaminsky would publicly reveal what the flaw was and how it could be exploited.

ASKING FOR TROUBLE

Kaminsky has not really discovered a new attack. Instead, he has found an ingenious way to breathe life into a very old one. Indeed, the basic flaw targeted by his attack predates the Internet itself.

The foundation of DNS was laid in 1983 by Paul Mockapetris, then at the University of Southern California, in the days of ARPAnet, the U.S. Defense Department research project that linked computers at a small number of universities and research institutions and ultimately led to the Internet. The system is designed to work like a telephone company's 411 service: given a name, it looks up the numbers that will lead to the bearer of that name. DNS became necessary as ARPAnet grew beyond an individual's ability to keep track of the numerical addresses in the network.

Mockapetris, who is now chairman and chief scientist of Nominum, a provider of infrastructure software based in Redwood, CA, designed DNS as a hierarchy. When someone types the URL for a Web page into a browser or clicks on a hyperlink, a request goes to a name server maintained by the user's Internet service provider (ISP). The ISP's server stores the numerical addresses of URLs it handles frequently—at least, until their time to live expires. But if it can't find an address, it queries one of the 13 DNS root servers, which directs the request to a name server responsible for one of the top-level domains, such as .com or .edu. That server forwards the request to a server specific to a single domain name, such as google.com or mit.edu. The forwarding continues through servers with ever more specific responsibilities—mail.google.com, or libraries.mit.edu—until the request reaches a server that can either give the numerical address requested or respond that no such address exists.

As the Internet matured, it became clear that DNS was not secure enough. The process of passing a request from one server to the next gives attackers many opportunities to intervene with false responses, and the system had no safeguards to ensure that the name server answering a request was trustworthy. As early as 1989, Mockapetris says, there were instances of "cache poisoning," in which a name server was tricked into storing false information about the numerical address associated with a website.

In the 1990s, the poisoner's job was relatively easy. The lower-level name servers are generally maintained by private entities: Amazon, for instance, controls the addresses supplied by the amazon.com name server. If a low-level name server can't find a requested address, it will either refer the requester to another name server or tell the requester the page doesn't exist. But in the '90s, the low-level server could also furnish the requester with the top-level server's address. To poison a cache, an attacker simply had to falsify that information. If an attacker tricked, say, an ISP's name server into storing the wrong address for the .com server, it could hijack most of the traffic traveling over the ISP's network.

Mockapetris says several features were subsequently added to DNS to protect the system. Requesting servers stopped accepting higher-level numerical addresses from lower-level name servers. But attackers found a way around that restriction. As before, they would refer a requester back to, say, the .com server. But now the requester had to look up the .com server's address on its own. It would request the address, and the attacker would race to respond with a forged reply before the real reply arrived. Ad hoc security measures were added to protect against this strategy, too. Now, each request to a DNS server carries a randomly generated transaction ID, one of 65,000 possible numbers, which the reply must contain as well. An attacker racing to beat a legitimate reply would also have to guess the correct transaction ID. Unfortunately, a computer can generate so many false replies so quickly that if it has enough chances, it's bound to find the correct ID. So the time to live, originally meant to keep name servers from being overburdened by too many requests, became yet another stopgap security feature. Because the requesting server will store an answer for some period of time, the attacker gets only a few chances to attempt a forgery. Most of the time, when the server needs a .com address, it consults its cache rather than checking with the .com server.

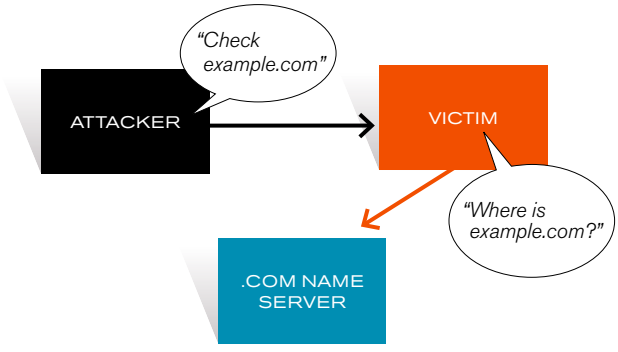
Kaminsky found a way to bypass these ad hoc security features—most important, the time to live. That made the system just as vulnerable as it was when cache poisoning was first discovered. Using Kaminsky's technique, an attacker gets a nearly infinite number of chances to supply a forgery.

Say an attacker wants to hijack all the e-mail that a social-networking site like Facebook or MySpace sends to Gmail accounts. He signs up for an account with the social network, and

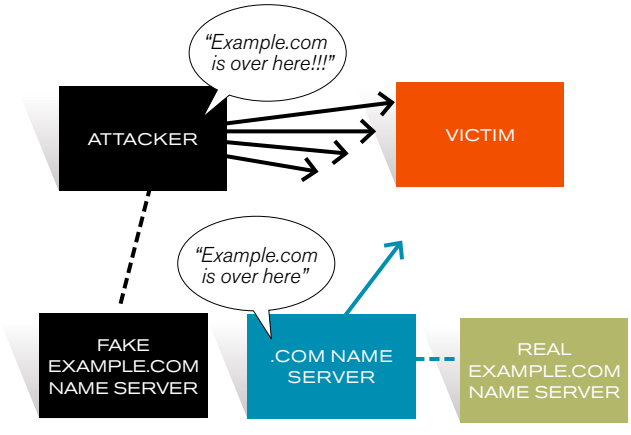
A CACHE-POISONING ATTACK

Cache poisoning causes a requesting server to store false information about the numerical address associated with a website. A basic version of the attack—without some of the more sophisticated techniques Kaminsky employs—is outlined below.

1. To begin, the attacker lures the victim's server into contacting a domain the attacker controls. The attacker could, say, claim to have forgotten a password, prompting the victim to respond by e-mail.



2. The victim performs a DNS lookup to find out where to send the e-mail. But the attacker's name server refers the victim to another server, such as that of example.com. Since the attacker knows that the victim will now start a DNS lookup for that server, he or she has an opportunity to attempt to poison its cache.



3. The attacker tries to supply a false response before the legitimate server can supply the real one. If the attacker guesses the right ID number, the victim accepts the false reply, which poisons the cache.

when he's prompted for an e-mail address, he supplies one that points to a domain he controls. He begins to log on to the social network but claims to have forgotten his password. When the system tries to send a new password, it does a DNS lookup that leads to the attacker's domain. But the attacker's server claims that the requested address is invalid.

At this point, the attacker could refer the requester to the google.com name servers and race to supply a forged response. But then he would get only one shot at cracking the transaction ID. So instead, he refers the requester to the nonexistent domains 1.google.com, then 2.google.com, then 3.google.com, and so on, sending a flood of phony responses for each. Each time, the requesting server will consult Google's name servers rather than its cache, since it won't have stored addresses for any of the phony URLs. The attack completely bypasses the limits set by the time to live. One of the attacker's forgeries is bound to get through. Then it's a simple matter to direct anything the requesting server intends for Google to the attacker's own servers, since the attacker appears to have authority for URLs ending in google.com. Kaminsky says he was able to pull off test attacks in as little as 10 seconds.

IN THE DARK

On July 8, Kaminsky held the promised press conference, announcing the release of the patch and asking other researchers not to speculate on the flaw. The hardware and software vendors had settled on a patch that forces an attacker to guess a longer transaction ID. Kaminsky says that before the patch, the attacker had to make tens of thousands of attempts to successfully poison a cache. After the patch, it would have to make billions.

News of the flaw appeared in the *New York Times*, on the BBC's website, and in nearly every technical publication. Systems administrators scrambled to get the patch worked into their systems before they could be attacked. But because Kaminsky failed to provide details of the flaw, some members of the security community were skeptical. Thomas Ptacek, a researcher at Matasano Security, posted on Twitter: "Saying it here first: doubting there's really any meat to this DNS security announcement."

Dino Dai Zovi, a security researcher best known for finding ways to deliver malware to a fully patched Macbook Pro, says, "I was definitely skeptical of the nature of the vulnerability, especially because of the amount of hype and attention versus the low amount of details. Whenever I see something like that, I instantly put on my skeptic hat, because it looks a lot like someone with a vested interest rather than someone trying to get something fixed." Dai Zovi and others noted that the timing was perfect to promote Kaminsky's Black Hat appearance, and they bristled at the request to refrain from speculation.

The lack of information was particularly controversial because system administrators are often responsible for evaluating patches

and deciding whether to apply them, weighing the danger of the security flaw against the disruption that the patch will cause. Because DNS is central to the operation of any Internet-dependent organization, altering it isn't something that's done lightly. To make matters worse, this patch didn't work properly with certain types of corporate firewalls. Many IT professionals expressed frustration at the lack of detail, saying that they were unable to properly evaluate the patch when so much remained hidden.

Concerned by the skepticism about his claims, Kaminsky held a conference call with Ptacek and Dai Zovi, hoping to make them see how dangerous the bug was. Both came out of the call converted. But although Dai Zovi notes that much has changed since the time when hardware and software manufacturers dealt with flaws by simply denying that security researchers had identified real problems, he also says, "We don't know what to do when the vulnerabilities are in really big systems like DNS." Researchers face a dilemma, he says: they need to explain flaws in order to convince others of their severity, but a vulnerability like the one Kaminsky found is so serious that revealing its details might endanger the public.

Halvar Flake, a German security researcher, was one observer who thought that keeping quiet was the more harmful alternative. Public speculation is just what's needed, he says, to help people understand what could hit them. Flake read a few basic materials, including the German Wikipedia entry on DNS, and wrote a blog entry about what he thought Kaminsky might have found. Declaring that his guess was probably wrong, he invited other researchers to correct him. Somehow, amid the commotion his post caused in the security community, a detailed explanation of the flaw appeared on a site hosted by Ptacek's employer, Matasano Security. The explanation was quickly taken down, but not before it had proliferated across the Internet.

Chaos ensued. Kaminsky posted on Twitter, "DNS bug is public. You need to patch, or switch to [Web-based] OpenDNS, RIGHT NOW." Within days, Metasploit, a computer security project that designs sample attacks to aid in testing, released two modules exploiting Kaminsky's flaw. Shortly after, one of the first attacks based on the DNS flaw was seen in the wild. It took over some of AT&T's servers in order to present a false Google home page, loaded with the attacker's own ads.

OUT OF COOKIES

Thirty minutes before Kaminsky took the stage at Black Hat to reveal the details of the flaw at last, people started to flood the ballroom at Caesar's Palace in Las Vegas. The speaker preceding Kaminsky hastened to wrap things up. Seats ran out, and people sat cross-legged on every square inch of carpet. Kaminsky's grandmother, who was sitting in the front row, had baked 250 cookies for the event. There were nowhere near enough.

Depending on your perspective, the way Kaminsky handled the DNS flaw and its patch was either dangerous grandstanding that left many Internet users vulnerable or a "media hack" necessary to train a spotlight on the bug's dangers.

Kaminsky walked up to the podium. "There's a lot of people out there," he said. "Holy crap." Kaminsky is tall, and his gestures are a little awkward. As of early August, he said, more than 120 million broadband customers had been protected, as Internet service providers applied patches. Seventy percent of Fortune 500 companies had patched their systems, and an additional 15 percent were working on it. However, he added, 30 to 40 percent of name servers on the Internet were still unpatched and vulnerable to his 10-second cache-poisoning attack.

Onstage, he flipped between gleeful description of his discovery's dark possibilities and attempts to muster the seriousness appropriate to their gravity. He spoke for 75 minutes, growing visibly lighter as he unburdened himself of seven months' worth of secrets. As he ended his talk, the crowd swept close to him, and he was whisked off by reporter after reporter.

Even those security experts who agreed that the vulnerability was serious were taken aback by Kaminsky's eager embrace of the media attention and his relentless effort to publicize the flaw. Later that day, Kaminsky received the Pwnie award for "most overhyped bug" from a group of security researchers. (The word "pwn," which rhymes with "own," is Internet slang for "dominate completely." Kaminsky's award is subtitled "The Pwnie for pwning the media.") Dai Zovi, presenting the award, tried to list the publications that had carried Kaminsky's story. He gave up, saying, "What *weren't* you in?"

"*GQ*!" someone shouted from the audience.

Kaminsky took the stage and spat out two sentences: "Some people find bugs; some people get bugs fixed. I'm happy to be in the second category." Swinging the award—a golden toy pony—by its bright pink hair, he stalked down the long aisle of the ballroom and out the door.

WHO'S IN CHARGE?

Depending on your perspective, the way Kaminsky handled the DNS flaw and its patch was either dangerous grandstanding that needlessly called public attention to the Internet vulnerability

or—as Kaminsky sees it—a "media hack" necessary to train a spotlight on the bug's dangers. Either way, the story points to the troubling absence of any process for identifying and fixing critical flaws in the Internet. Because the Internet is so decentralized, there simply isn't a specific person or organization in charge of solving its problems.

And though Kaminsky's flaw is especially serious, experts say it's probably not the only one in the Internet's infrastructure. Many Internet protocols weren't designed for the uses they're put to today; many of its security features were tacked on and don't address underlying vulnerabilities. "Long-term, architecturally, we have to stop assuming the network is as friendly as it is," Kaminsky says. "We're just addicted to moving sensitive information across the Internet insecurely. We can do better."

Indeed, at another security conference just days after Kaminsky's presentation at Black Hat, a team of researchers gave a talk illustrating serious flaws in the Internet's routing border gateway protocol. Like Kaminsky, the researchers had found problems with the fundamental design of an Internet protocol. Like the DNS flaw, the problem could allow an attacker to get broad access to sensitive traffic sent over the Internet.

Many experts say that what happened with the DNS flaw represents the best-case scenario. Mischel Kwon, director of US-CERT, a division of the Department of Homeland Security that helped get out the word about the DNS bug, hopes the network of organizations that worked together in this case will do the same if other flaws emerge. Though there's no hierarchy of authority in the private sector, Kwon says, there are strong connections between companies and organizations with the power to deploy patches. She says she is confident that, considering the money and effort being poured into improving security on the Internet, outdated protocols will be brought up to date.

But that confidence isn't grounded in a well-considered strategy. What if Kaminsky hadn't had extensive connections within the security community or, worse, hadn't been committed to fixing the flaw in the first place? What if he had been a true "black hat" bent on exploiting the vulnerability he'd discovered? What if his seemingly skillful manipulation of the media had backfired, and the details of the flaw had become known before the patch was in place?

What's more, even given the good intentions of researchers like Kaminsky, fixing basic flaws in the Internet isn't easy. Experts agree that the DNS problem is no exception. Several proposals are on the table for solving it by means more reliable than a patch, mostly by reducing the trust a requesting server accords a name server. Proposals range from relatively simple fixes, such as including even more random information in the requests made to name servers, to moving the entire system over to a set of protocols that would let name servers sign their responses cryptographically.

In the meantime, both Kaminsky and Vixie say attackers have started to make use of the DNS flaw, and they expect more trouble to come. Kaminsky notes that the flaw becomes particularly dangerous when exploited along with other vulnerabilities. One such combination, he says, would allow an attacker to take over the automatic updates that a software vendor sends its customers, replacing them with malware. Kaminsky says he's spent the last several months on the phone to companies that would be attractive targets for that kind of attack, such as certificate authorities, social networks, and Internet service providers, trying to convince them to patch as soon as possible.

"The scary thing," Dai Zovi says, "is how fragile [the Internet] is. ... And what are we going to do about it?" TR

ERICA NAONE IS AN ASSISTANT EDITOR AT *TECHNOLOGY REVIEW*.

Nuclear Deterrence in the Age of Nuclear Terrorism

AN ATTACK ON ONE OF THE GREAT CITIES OF THE WORLD IS ALMOST INEVITABLE. BUT WITH BETTER DETECTION TECHNOLOGIES, A NEW INTERNATIONAL ALLIANCE COULD STILL PREVENT CATASTROPHE.

By GRAHAM ALLISON

On October 11, 2001, one month after the terrorist assault on the World Trade Center and the Pentagon, President George W. Bush faced a terrifying prospect. At that morning's daily presidential intelligence briefing, George Tenet, the director of central intelligence, informed the president of reports from a CIA agent code-named Dragonfire that al-Qaeda terrorists possessed a 10-kiloton nuclear bomb, evidently stolen from the Russian arsenal. According to Dragonfire, the weapon was in New York City.

The government dispatched a nuclear-emergency support team. Under a cloak of secrecy that excluded even Mayor Rudolph Giuliani, these experts searched for the bomb. On a normal workday, half a million people crowd the area within a half-mile radius of Times Square. A noon detonation in midtown Manhattan would kill them all. The wounded would overwhelm hospitals and emergency services. Firemen would fight a ring of uncontrolled blazes for days afterward.

In the hours that followed, Condoleezza Rice, then the national security advisor, analyzed what strategists call the "problem from hell." During the Cold War, the United States and the Soviet Union each knew that an attack against the other would elicit a retaliatory strike of commensurate or greater measure; but al-Qaeda had no such fear of reprisal.

Concerned that al-Qaeda could have smuggled a nuclear weapon into Washington as well, the president ordered Vice President Dick Cheney to leave the capital for an "undisclosed location," where he would remain for weeks. Several hundred federal employees from more than a dozen government agencies joined the vice president at this secret site—the core of an alternative government.

Six months earlier, the CIA's Counterterrorism Center had picked up chatter in al-Qaeda channels about an "American Hiroshima." The CIA knew that Osama bin Laden's fascination with nuclear weapons went back at least to 1993, when he attempted to buy highly enriched uranium of South African origin. Al-Qaeda operatives were alleged to have negotiated with Chechen separatists in Russia to buy a nuclear warhead, which the Chechen warlord Shamil Basayev claimed to have acquired from Russian arsenals. The CIA's special task force on al-Qaeda had noted the terrorist group's emphasis on thorough planning, intensive training, and repetition of successful tactics. The task force highlighted al-Qaeda's preference for symbolic targets and spectacular attacks.

As CIA analysts examined Dragonfire's report and compared it with other bits of information, they noted that the September attack on the World Trade Center had set the bar higher for future terrorist acts. Psychologically, a nuclear attack would stagger the world's imagination. New York was, in the jargon of national-security experts, "target rich."

As it turned out, of course, Dragonfire's report was a false alarm. But what the case teaches us is this: the U.S. government was unable to dismiss the possibility of such an attack on any scientific or logical grounds.

PREVENTING NUCLEAR CATASTROPHE

Given current policies and practices, a nuclear terrorist attack that devastates one of the great cities of the world is inevitable. In my judgment, if governments do no more and no less than they are doing today, the odds of such an event within a decade are more than 50 percent.

This estimate is, in effect, my best guess, since there is no methodology for predicting an unpredictable catastrophe. But my judgment is informed by having analyzed issues of nuclear danger for more than three decades, during which I served as a special advisor to U.S. secretary of defense Caspar Weinberger

BETTMANN/CORBIS

Illustration by MARC YANKUS

in the Reagan administration and as assistant secretary of defense for policy and plans in the Clinton administration.

Others have offered more conservative but still dire assessments. My Harvard colleague Matthew Bunn has created a model that estimates the probability of a nuclear terrorist attack over a 10-year period to be 29 percent—identical to the average estimate from a poll of security experts commissioned by Senator Richard Lugar in 2005.

Still others are more pessimistic than I. Former secretary of defense William Perry, for one, has suggested that my work underestimates the risk. Richard Garwin, a designer of the hydrogen bomb (whom the Nobel laureate physicist Enrico Fermi called "the only true genius I had ever met"), told Congress in March 2007 that he estimated a "20 percent per year probability" of a nuclear explosion in an American or European city. And Warren Buffett, the world's most successful investor and a legendary oddsmaker in pricing insurance policies for unlikely but catastrophic events, concludes that nuclear terrorism is "inevitable." He has said, "I don't see any way that it won't happen."

But there is some good news: nuclear terrorism is nonetheless preventable. There are feasible, affordable measures that, if taken, would reduce the likelihood of a successful nuclear terrorist attack to nearly zero.

The centerpiece of a strategy to prevent nuclear terrorism must be to deny terrorists access to nuclear weapons or materials. To this end, my 2004 book, *Nuclear Terrorism: The Ultimate Preventable Catastrophe,* proposes a strategy for shaping a new international security order according to a doctrine of "Three No's":

- No loose nukes: all nuclear weapons and weapons-usable material must be secured, on the fastest possible timetable, as tightly as the gold in Fort Knox.
- No new nascent nukes: no nation must develop new capabilities to enrich uranium or reprocess plutonium.
- No new nuclear-weapons states: we must draw a line under the current eight and a half nuclear powers and say unambiguously, "Stop. No more."

In the last 17 years, efforts have been made to address the threat. The danger of "loose nukes" came into focus in 1991, during the Soviet Union's collapse. After the failed coup attempt against Mikhail Gorbachev in August 1991, I composed a private memo to the chairman of the Joint Chiefs of Staff, Colin Powell, titled "Sounding the Alarm." "Soviet disunion could create additional nuclear states, provoke struggles for control of Soviet nuclear weapons, and lead to a loss of control of strategic or nonstrategic nuclear weapons," I wrote.

In the weeks that followed, President George H. W. Bush and Gorbachev agreed to what was later called the "unilateral declarations." The United States removed all tactical nuclear weapons from its operational forces and challenged the Soviet Union to do likewise.

Gorbachev's response was encouraging. With the aid of U.S. funding, secured through the Coöperative Threat Reduction Program sponsored by Lugar and his Senate colleague Sam Nunn, thousands of the Soviet Union's 21,700 tactical nuclear weapons stationed in 14 of the Soviet Union's 15 constituent republics were returned to Russia. Moreover, 3,200 strategic nuclear weapons stationed in Belarus, Kazakhstan, and Ukraine, most atop missiles that targeted American cities, were eliminated. Today, there are no nuclear weapons in any of the former Soviet states except Russia.

By now, U.S.-sponsored security upgrades have been completed for 80 percent of Russia's nuclear material and warhead sites. As of June 2008, 7,292 strategic nuclear warheads had been deactivated (79 percent of the Nunn-Lugar target for 2012), and 708 intercontinental ballistic missiles had been destroyed (65 percent of the 2012 target), along with 30 nuclear submarines capable of launching ballistic missiles (86 percent of the 2012 target). Several of the 2012 targets have already been met, and 25 classified sites on 12 Russian bases have been secured two years ahead of schedule.

During the 2004 presidential campaign, in the first televised debate between President George Bush and Senator John Kerry, the moderator asked each candidate, "What is the single most serious threat to the national security of the United States?" In rare agreement, Kerry and Bush both cited nuclear terrorism. As the president said, "I agree with my opponent that the biggest threat facing the country is weapons of mass destruction in the hands of a terrorist network." During the 2005 Bratislava summit, President Bush and Russian president Vladimir Putin for the first time accepted responsibility for addressing the threat and for ensuring that their governments secure loose nuclear material in their countries as quickly as possible. They assigned responsibility for securing nuclear materials to individuals (U.S. energy secretary Samuel W. Bodman and his Russian counterpart, the head of the Russian Federal Atomic Energy Agency) and held them accountable by requiring regular progress reports.

But the missteps, missed opportunities, and wrong turns of the past two decades are weightier than the successes. The nuclear superpowers failed to take advantage of the end of the Cold War to dramatically reduce and restructure nuclear arsenals—or, at least, to honor their commitments under the 1968 Non-Proliferation Treaty (NPT) rigorously enough to

persuade other states to honor theirs. India and Pakistan tested nuclear bombs and began deploying active nuclear arsenals. North Korea withdrew from the NPT, used technologies acquired under the treaty to produce plutonium for an estimated eight nuclear bombs, and tested a nuclear weapon. In 2005, an NPT review conference collapsed amid general intransigence. Most recently, Iran has defied three U.N. Security Council resolutions demanding that it suspend its nuclear enrichment activity.

Of everything on this list, the most worrying is nuclear proliferation in North Korea. That country is among the most dangerous potential sources of a nuclear bomb that Osama bin Laden, or someone like him, could use to destroy the heart of New York or Washington, DC. In 2004, Pyongyang had two bombs' worth of plutonium. It has since developed an arsenal of around 10 bombs.

Consider the consequences if just one nuclear bomb exploded in just one U.S. city. The immediate reaction would be to block all entry points to prevent another bomb from reaching its target, disrupting the global flow of raw materials and manufactured goods. Vital markets for international products would disappear, and financial markets would crash. Researchers at Rand, a think tank funded by the U.S. government, have estimated that a nuclear explosion at the Port of Long Beach, CA, would cause immediate indirect costs of more than $1 trillion worldwide and that shutting down U.S. ports would cut world trade by 7.5 percent.

The total, long-term economic effects would be much worse, however, and would reverberate well beyond the developed world. As former U.N. secretary-general Kofi Annan has warned, a nuclear terrorist attack would not only "cause widespread death and destruction" but "thrust tens of millions of people into dire poverty." This would, he observed, create "a second death toll throughout the developing world."

George Tenet, the director of central intelligence, informed the president that a CIA agent code-named Dragonfire had reported that al-Qaeda terrorists possessed a 10-kiloton nuclear bomb, evidently stolen from the Russian arsenal. According to Dragonfire, this weapon was in New York City.

As the 2004 U.N. High-Level Panel on Threats, Challenges, and Change concluded, "We are approaching a point at which the erosion of the non-proliferation regime could become irreversible and result in a cascade of proliferation."

After the United States invaded Afghanistan in the aftermath of 9/11, the Taliban government was toppled and al-Qaeda's headquarters and leadership, including Osama bin Laden and his deputy Ayman al-Zawahiri, were evicted from the country. But note the supreme irony: having entered office with a bearded madman in medieval Afghanistan plotting and training foot soldiers for a massive terrorist attack on the United States, President Bush will probably hand the reins to his successor as this same bearded madman plots even deadlier attacks on our country—but now he will be plotting them from training camps in Pakistan, a nuclear state.

No one who has examined the evidence has any doubt that al-Qaeda is deadly serious about exploding a nuclear bomb. As former CIA director George Tenet reveals in his memoir, "The most senior leaders of al Qaeda are still singularly focused on acquiring WMD. ... The main threat is the nuclear one. I am convinced that this is where Osama bin Laden and his operatives desperately want to go."

Preventing such a calamity will require policy leadership, institutional innovation, international coöperation, and hard work. The prospects for success can be enhanced by capitalizing on a competitive advantage of the United States: technology. Al-Qaeda and other global terrorists are technologically challenged, and technologically advanced countries must exploit this asymmetry. If we do, our ability to secure, trace, and dismantle weapons of mass destruction will exceed terrorist organizations' abilities to procure them.

NUCLEAR CSI: UNAMBIGUOUS ATTRIBUTION

Could states be held as accountable for the nuclear weapons they create (and the material from which such weapons could be made) as they are for the nuclear warheads their governments choose to deploy? The U.S. government considered this question during the Cold War—and answered it, though the answer offers cold comfort. Recall the most dangerous moment of the Cold War, the Cuban Missile Crisis of October 1962. The United States discovered the Soviet Union attempting to sneak nuclear-tipped missiles into Cuba. President John F.

Kennedy confronted his Soviet counterpart, Nikita Khrushchev, and demanded that the missiles be withdrawn. As the crisis unfolded, American strategists worried that Khrushchev might transfer control of the nuclear arsenal in Cuba to a young, hotheaded revolutionary named Fidel Castro.

After conducting careful deliberations, Kennedy issued an unambiguous warning to Khrushchev and the Soviet Union: "It shall be the policy of this nation to regard any nuclear missile launched from Cuba against any nation in the Western Hemisphere as an attack by the Soviet Union on the United States, requiring a full retaliatory response upon the Soviet Union." Khrushchev well understood what Kennedy was talking about: the certain prospect of a full-scale nuclear war.

In the years after the crisis, nuclear strategists considered the array of scenarios in which one or a small number of Soviet nuclear weapons might explode on American soil. In one such scenario, a single missile is launched against an American city in an attack the Soviet leader claims is "accidental" or "unauthorized." For example, a Soviet leader calls the American president on the hotline to inform him that a Soviet missile commander has gone insane and, without authorization, launched a single missile with a nuclear warhead against an American city. How should the president respond?

Grisly though the logic was, the canonical answer was a strategy of "an eye for an eye." Herman Kahn, author of the controversial 1960 work *On Thermonuclear War*, described this approach as "graduated, or controlled deterrence ... of provocative actions by a counteraction which is expected to be so effective that the net effect of the 'aggressor's' action is to cause him to lose in position." The U.S. plan was to retaliate by delivering a nuclear warhead capable of destroying a counterpart Russian city. Pentagon planners developed lists of such unfortunately twinned cities in support of that policy.

Who knows whether an American president would have responded to the accidental destruction of Minneapolis by destroying Minsk. But Soviet leaders' belief that a president *might* do so undoubtedly reinforced their determination that no accidental launches occur.

MODERN DETERRENCE

As one moves beyond Cold War logic to the crueler, more complex logic of nuclear terrorism, the question is whether personal accountability for terrorist use of a nuclear weapon manufactured by a given state can deter the state's leader from selling weapons to terrorists. What's more, the question of accountability applies equally well in cases where proliferation is not willful. If leaders believe that they will be held accountable for their nuclear weapons even if those weapons are stolen, will they be better motivated to prevent theft?

The answer depends on two further questions. First, can we attribute the weapon to its source? Second, how will accountability be defined politically, and how can it be enforced?

As I wrote in *Technology Review* in the summer of 2005 *(see "Nuclear Accountability," July 2005 and at technologyreview.com)*, "The technological prerequisite for rethinking the unthinkable is nuclear forensics: the ability to identify a bomb's source from radioactive debris left after it explodes." A credible capacity to identify nuclear material definitively and quickly is essential. If the leader of a government—say, Kim Jong Il of North Korea—knew that the United States would be able to identify his "fingerprints" on a nuclear weapon he sold to terrorists, it should be a useful deterrent. Similarly, nuclear custodians, scientists, and others whose main motivation for helping terrorists is financial, not ideological, would probably be more hesitant to do so if they could be found out.

A post-9/11 study by the National Research Council (NRC), *Making the Nation Safer: The Role of Science and Technology in Countering Terrorism*, concludes that such detection is technically feasible: "The technology for developing [post-explosion nuclear attribution] exists but needs to be assembled, an effort that is expected to take several years."

Nuclear Forensics: Role, State of the Art, Program Needs, a 2008 study by the Joint Working Group of the American Physical Society (APS) and the American Association for the Advancement of Science (AAAS) that is the best recent public report on the subject, concurs with the NRC's judgment: "The underlying scientific disciplines ... are understood adequately for the purpose of forensics." Nevertheless, the report concludes that the current state of the art will not yield maximally effective deterrence. We lack a central global database of unique material signatures that countries can promptly access in the event of a nuclear detonation. Even if such a database existed, states would not be fully prepared to take advantage of it in a day-after scenario. The APS and AAAS report that "neither equipment nor people are at the level needed to provide as prompt and accurate information for decision makers as is possible."

The report suggests that two separate technological initiatives are critical to improving U.S. forensic capability. The first is the development of equipment that can provide immediate, rough assessments in the field—portable instruments capable of what the APS and AAAS call "all-weather, all-scenario rapid response." The second is improvement of equipment for performing more detailed analysis of forensic samples. According to the report, the equipment in the U.S. Department of Energy's labs must be upgraded to "world standards."

Assuming that there is an attack and we have identified the source, we come to the much more difficult question. What response is appropriate?

A GLOBAL ALLIANCE AGAINST NUCLEAR TERRORISM

Establishing an accepted principle of nuclear accountability will be a major international undertaking. It should begin with the United States and Russia, each of which has a special obligation to address this challenge, since they created it—and since they still own 95 percent of all nuclear weapons. They should take the lead in establishing a new global alliance against nuclear terrorism. The mission of the alliance should be to minimize the risk of such terrorism anywhere by taking every action physically, technically, and diplomatically possible to prevent nuclear weapons or materials from falling into the hands of terrorists.

Membership in the alliance would require an unambiguous commitment to the principle of assured nuclear security. States would have to guarantee that all nuclear weapons and materials in their territories were beyond the reach of terrorists or thieves. And states' means of securing these materials would have to be sufficiently transparent that leaders of all member states could reassure their own citizens that terrorists would never get a nuclear bomb from another alliance member.

U.N. Security Council Resolution 1540 already obligates all member states to develop and maintain "appropriate, effective" measures to secure weapons and materials, but this obligation has unfortunately not been reinforced by specific, mandatory standards. However, the Nunn-Lugar Expansion Act, adopted by Congress in 2003, authorized the Nunn-Lugar program to operate outside the former Soviet Union to address proliferation threats. Moreover, the Bush administration has reportedly provided $100 million in technology and related assistance to help Pakistan secure its vulnerable nuclear arsenal.

The Global Initiative to Combat Nuclear Terrorism announced by Presidents Bush and Putin at the St. Petersburg G8 summit in July 2006 was another step in the right direction. But the alliance against nuclear terrorism that I am proposing would go beyond declarations; it would require specific actions in exchange for specific benefits. The actions would include defining the security levels of weapons and weapons-usable materials, as well as assuring others that these levels of security had been achieved. Leaders of complying states would participate in an annual summit, and full alliance members would also be entitled to intelligence sharing, assistance with security technology, participation in interdiction exercises, and postdetonation medical and cleanup aid.

The leader of a country that joined the alliance would have to take responsibility for the country's doing everything technically possible, as fast as possible, to prevent nuclear terrorism. Meanwhile, member states would be required to deposit samples of nuclear materials in an international library that would be available for use in identifying the source of any weapon or material that found its way into terrorists' hands.

Members of the alliance would together clarify the practical meaning of accountability in the event that a weapon or material was used by terrorists against another state. If nuclear weapons or materials should be stolen, states that had satisfied the requirements for assured nuclear security, met the new standards in securing their materials, and made their safeguards sufficiently transparent to the other members would be judged less negligent. States that were unwilling to participate fully in the alliance would automatically raise suspicions.

Members of the alliance would also undertake to clarify the consequences of knowingly allowing nuclear materials to fall into terrorist hands. Those consequences would not necessarily involve military retaliation; alternatives such as exacting financial reparations would certainly be explored and might prove more realistic. Consequences would also be different for different violators, since threatening nuclear retaliation against Russia would not be credible.

Currently, the only state that could plausibly choose to sell a nuclear bomb to terrorists is North Korea. Since it may have 10 weapons, the sale of one or two would make little difference to its deterrent posture. An economically desperate mafioso state, North Korea has demonstrated a willingness to sell whatever it makes to whoever will pay.

To deter Kim Jong Il from selling a nuclear weapon to terrorists, the U.S. government should act now to convince him that North Korea will be held accountable for every weapon of North Korean origin. Ideally, the United States would act in concert with Russia and China in taking a page from John F. Kennedy's playbook during the Cuban Missile Crisis. The announced policy of nuclear accountability would warn Kim unambiguously that the explosion of any nuclear weapon of North Korean origin on the territory of alliance states or their allies would be met with a full retaliatory response ensuring that it could never happen again.

Success in the war on terrorism will require a combination of policy imagination and technological inventiveness. Visualizing the alternative—a world of nuclear anarchy—should stimulate us to rethink nuclear unthinkables. TR

WWW Watch an interview with Graham Allison on the threat of nuclear terrorism: **technologyreview.com/essay**

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FICTION

Glass

SOME PEOPLE FEEL NO EMPATHY. AN EXPERIMENTAL DRUG MAKES THEM TAKE A HARD LOOK IN THE MIRROR.

By DARYL GREGORY

"It's one of the crybabies," the guard told her. "He's trying to kill one of the psychos."

Dr. Alycia Liddell swore under her breath and grabbed her keys. Only two weeks into the drug trial and the prisoners were changing too fast, starting to crack.

In the hospital wing, a dozen guards crowded around an open cell door. They were strapping on pads, pulling on helmets, slapping billy clubs in their palms. It was standard procedure to go through this ritual in full view of the prisoners; more often than not they decided to walk out before the extraction team went in.

The shift lieutenant waved her to the front of the group. "One of your babies wants to talk to you," he said.

She leaned around the door frame. In the far corner of the cell, wedged between the toilet and the wall, two white men sat on the floor, one behind the other, like bobsledders. Lyle Carpenter crouched behind, his thin arms around Franz Lutwidge's broad chest. Lyle was pale and sweating. In one hand he gripped a screwdriver; the sharpened tip trembled just under Franz's walrus-fat chin.

Franz's eyes were open, but he looked bored, almost sleepy. The front of his orange jumpsuit was stained dark.

Both men saw her. Franz smiled and, without moving, somehow suggested a shrug: *Look at this fine mess.* Lyle, though, almost let the screwdriver fall. "Doc. Thank God you're here." He looked ready to burst into tears.

The doctor stepped back from the door. "Franz is bleeding," she said to the lieutenant.

"Lyle stabbed him in the chest. It looks like it stopped, but if he's bleeding internally we can't wait for the negotiation team. I thought you might want to take a crack at getting Lyle to drop the weapon."

"If I can't?" But she already knew the answer.

"I'll give you three minutes," he said.

They wanted her to put on pads and a helmet, but she refused. Lyle and Franz, like the other 14 men in the GLS-71 trial, were low-risk prisoners: liars, thieves, con men, nonviolent offenders. The review board wouldn't allow her to enroll the more aggressive prisoners. Still, she'd succeeded in finding men with very high scores on Hare's Psychopathy Checklist. They were all-star psychopaths—or sociopaths, to use the term some of her colleagues preferred.

The lieutenant let her take only three steps into the cell before he said, "That's good."

Lyle's eyes were fixed on hers. She smiled, then let concern show in her face. "Why don't you tell me what's going on, Lyle?"

Franz said, "I'm not sure he knows himself."

"Shut up!" Lyle said, and the hand holding the screwdriver shook. Franz lifted his chin slightly.

"Just focus on me," she said to Lyle. "If you put down the weapon, we can talk about what's upsetting you."

"I fucked up, Doctor Liddell. I tried to stop him, but I couldn't—"

"Call me Alycia, Lyle."

"Alycia?" He looked surprised—and touched. She never permitted the prisoners to call her by her first name.

Franz made a derisive noise, but Lyle seemed not to hear him. "I was doing this for you, Alycia. I was just going to kill myself, but then when he told me what he was going to do, I knew I had to take care of him first." He flexed his fingers along the screwdriver's grip. "I stabbed him, going right for the heart. Then he jumped up and I knew I'd missed. I knew I had to hit him again, but I just—froze." He looked at her, his eyes shining with tears. "I couldn't do it! I saw what I'd done and I almost threw up. I felt like I'd stabbed my*self*. What the hell is happening to me?"

That's what we're trying to find out, she thought. GLS-71 was an accidental treatment, a failed post-stroke drug that was intended to speed speech recovery. Instead, it found the clusters of mirror neurons in Broca's area and increased their rate of firing a thousandfold.

Mirror neurons were specialist cells. See someone slapped, and the neurons associated with the face lit up in synchrony. See someone kicked, and the brain reacted as if its own body were under attack. Merely imagining an act, or remembering it, was enough to start a cascade of hormonal and physical responses. Mirror neurons were the first cogs to turn in the complex systems of attachment, longing, remorse. They were the trip wires of empathy.

Except for people like her all-stars. In psychopaths, the mirrors were dark.

"I know you must be confused," she said. "GLS is making you feel things you've never felt before."

Illustrations by OWEN SMITH

"I even feel sorry for this piece of shit, even though I know what he was going to do to you. What he still wants to do." He nodded toward the bed. "This morning, he showed me where he was keeping the knife. He told me exactly how he was going to rape you. He told me the things he was going to force you to do."

Dr. Liddell looked at Franz. The man wasn't smiling—not quite. "You could have called a guard, Lyle. You could have just warned me."

"See, that's the thing—I wanted to hurt him. I thought about what he was going to do to you, and I felt ... I felt—"

"*Luuv*," Franz said.

The screwdriver's tip jerked. A thin dark line appeared along Franz's neck like the stroke of a pen.

"You don't know what love is!" Lyle shouted. "He hasn't changed at all, Alycia! Why isn't it working on him?"

"Be*cause*," Franz said, his tone condescending and professorial despite the cut and the wavering blade at his throat. "I'm in the control group, Lyle. I didn't receive GLS."

"We all got the drug," Lyle said. Then: "Didn't we?"

Franz rolled his eyes. "Could you please explain to him about placebos, *Alycia*?"

She decided then that she'd like to stab Franz herself. He was correct; he was in the control group. The trial was supposed to be a double-blind, randomized study, with numbered dosages supplied by the pharmaceutical company. But within days she knew which eight men were receiving the real dose. Guards and prisoners alike could sort them as easily as if they were wearing gang colors: the psychos and the crybabies.

"He's playing you, Lyle," she told him. "Pushing your buttons. That's what people like Franz do."

"You think I don't know that? I *invented* that shit. I used to be fucking bulletproof. No one got to me, no one fucked with me. Now, it's like everybody can see right through me."

The lieutenant cleared his throat. Dr. Liddell glanced back. The mass of helmeted men behind him creaked and flexed, a machine ready to be launched.

Franz hadn't missed the exchange. "You're running out of time, Lyle," he said. "Any second now they're going to come in here and crack you like an egg. Then they're going to take you off to solitary, where you won't be seeing your girlfriend anymore."

"What?" Lyle asked.

"You don't think they're going to let you stay in the program after this, do you?"

Lyle looked at her, eyes wide. "Is that true? Does that mean you'll stop giving me GLS?"

They're going to stop giving it to all of you, she thought. After Lyle's breakdown, the whole nationwide trial would be canceled. "Lyle, we're not going to stop the GLS unless you want to."

"Stop it? I never want to be the guy I was before. Nobody felt real to me—everybody was like a cartoon, a nothing on the other side of the TV screen. I could do whatever I wanted with them, and it didn't bother me. I was like him."

Franz started to say something, and Lyle pressed the screwdriver blade into his neck. The two men winced in unison.

"You don't know what he's like," Lyle said. "He's not just some banker who ripped off a couple hundred people. He's a killer."

"What?"

"He shot two teenagers in Kentucky, buried them in the woods. Nobody ever found them. He *brag*s about it."

"Stories," Franz said.

Dr. Liddell stepped closer and knelt down next to Franz's outstretched legs. "Lyle, I swear to you, we'll keep you on GLS." She held out a hand. "Give the weapon to me, Lyle. I know you were trying to protect me, but you don't have to be a murderer. You don't have to throw away everything you've gained."

"Oh, please," Franz said.

Lyle squeezed shut his eyes, as if blinded.

"I give you my word," she said, and placed her hand over his. "We won't let the old you come back." After a long moment she felt his grip relax. She slowly pulled the screwdriver from his fist.

Shouts went up behind her, and then she was shoved aside. The extraction team swarmed over the two men.

Three days later she came down to solitary. She brought four guards as escort.

"You know, you're good," Franz said. "I almost believed you myself." He lay on the bed with his jumpsuit half unzipped, revealing the bandages across his chest. The blade had missed the lung and the heart, tearing only muscle. The wound at his neck was covered by two long strips of gauze. He'd be fine in a few weeks. "'I give you my word.' Genius."

"I did what I had to do."

"I've used that one too. But did you have to break his heart? Poor Lyle was in love with you, and you out-and-out lied to him. There was no way you were going to keep him on GLS—you made a petty thief into a suicidal, knife-wielding maniac. How can they put anyone on that stuff now?"

"There'll be another trial," she said. "Smaller dosages, perhaps, over a longer period of time."

"That doesn't help Lyle, now, does it?"

"He's going to live, that's the important thing. I have plenty of GLS left, so I can bring him down slowly. The suicidal thoughts are already fading. In a few days he won't be bothered by remorse. He'll be back to his old self."

"And then someday you'll get to wring him out again." He shook his head, smiling. "You know, there's a certain coldness about you, Doctor—has anyone ever told you that? Maybe you should try some GLS yourself."

"Tell me about Kentucky," she said.

"Kentucky?" Franz shrugged, smiled. "That was just some bullshit to get Lyle worked up."

She frowned. "I was hoping you'd want to talk about it. Get it off your chest." She turned to one of the guards, and he handed her the nylon bag from her office. "Well, we can talk again in a few days."

He blinked, and then he understood. "You can't do that. I'll call my lawyer."

"I don't think you'll want a lawyer any time soon." She unzipped the bag and lifted out the plastic-sealed vial. "I have a lot of GLS, and only one patient now." The guards rushed forward to pin the man to the bed.

She popped the needle through the top of the vial and drew back the plunger. The syringe filled with clear, gleaming liquid.

"One thing I'm sure of," she said, half to herself. "In a few days, Franz, you'll thank me for this." TR

DARYL GREGORY'S SHORT STORIES HAVE APPEARED IN *THE MAGAZINE OF FANTASY AND SCIENCE FICTION*, *ASIMOV'S SCIENCE FICTION*, AND *THE YEAR'S BEST SF*. HIS FIRST NOVEL, *PANDEMONIUM*, WAS RECENTLY PUBLISHED BY DEL REY BOOKS.

FICTION

The Distant Sound of Engines

By ALGIS BUDRYS

[Editor's note: Science fiction author Algis Budrys died on June 9, 2008; a review of his eventful career begins on page 80. The following story originally appeared in the March 1959 issue of The Magazine of Fantasy and Science Fiction.*]*

"Len? Lenny?" The unearthly man in the next bed was trying to wake me up.

I lay in the dark, my hands behind my head, listening to the traffic going by the hospital. Even late at night—and it was late whenever the man in the next bed dared to talk to me—the traffic outside was fairly heavy because the highway ran straight through town. That had been a lucky thing for me, because the ambulance attendant never had been able to stop the flow of blood out of my legs. Another half mile, another two minutes, and I would have been as dry as a cast-off snakeskin.

But I was all right, now, except that the jack-knifing truck had taken my legs off under the dashboard. I was alive, and I could hear the trucks going by all night. The long, long rigs; semi-trailers, tandems, reefers ... coming up the seaboard from Charleston and Norfolk, going on to New York ... coming down from Boston, from Providence ... Men I knew, driving them. Jack Biggs. Sam Lasovic. Tiny Morrs, with the ring finger of his right hand missing at the first joint. I was one up on Tiny, for sure.

Job in the dispatcher's office waiting for you, Lenny, I said to myself. No sweat. No more bad coffee, cold nights, sandpaper eyes. Getting a little old for the road, anyhow. Thirty-eight. Sure.

"Lenny ... "

The best the man in the next bed would do was whisper. I wondered if he wasn't just afraid. He was afraid to talk at all in the daytime, because the nurses simply stuck a new needle in him every time he made a sound. Stuck it through a thin place in the bandages, they did, and walked away in a hurry. Sometimes they missed, and sometimes only some of the morphine got under his skin, so that only his arm went numb. The man in the next bed bragged about the times that happened. He tried to make them miss, moving his arms a little. Sometimes they noticed, but more often they didn't.

He didn't want the needle, the man in the next bed didn't. The needle took away the pain, and without the pain, with bandaging all over his face, he didn't have any proof he was alive. He was a stubborn, smart man, fighting back that way, because he'd developed a craving for the stuff, even not being like you and me. I mean, from some different place.

"*Lenny* ... "

"Hunh?" I said, fogging my voice. I always made him wait. I didn't want him to know I stayed awake all night.

"Awake?"

"Now."

"I'm sorry, Len."

"Okay," I said quickly, I didn't want him feeling obligated to me. "It's all right. I get plenty of sleep daytimes."

"Len. The formula for exceeding the velocity of light is ... " And he began giving me the figures and letters.

Last night it had been the exact proportions of the metals in a high-temperature resistant alloy; the melting and pouring techniques for it; the hardening process. The night before, hull specifications. I listened until he was through.

"Have you got that, Lenny?"

"Sure."

"Read it back to me."

I worked in a diner three years, once. I could remember anything anybody told me—I didn't care how complicated—and rattle it off right back to him. It's a trick; you wipe your mind clean, open your ears, and in it comes: "Two grilled cheese to go; bacon and tomato, white toast, no mayonnaise. Three coffees; one black, no sugar; one light and sweet; one regular." You open your mouth, turn toward the sandwich man, and out it comes: "G.A.C. on two, seaboard. B.T. down, hold the mayo." You turn toward the coffee cups and put out your hands. Your fingers grab the cups, and you move to the spigot

on the urn. You tap the milk jug handle three times over one cup, twice over the other. The third cup slides by automatically. The important part of your mind is a million miles away. You put the coffees down, and your mind wipes out that part of the order. The sandwich man hands you two waxpaper-wrapped squares and a plate with the B.T. on it. You give them to the customers, and your mind wipes out the rest of it. It's gone, used up, and all the time the important part of your mind is a million miles away.

I listened to the rigs going up a hill in compound. Pittsburgh, Scranton, Philadelphia ... Washington, Baltimore, Camden, Newark ... A diesel went by—a flatbed, with I beams for a load—while I was reading back the last part of what he'd told me.

"That's right, Lenny. That's *right!*"

I suppose it was. In a diner, you eat the orders you foul up.

"Any more tonight?" I asked him.

"No. No, that's enough. I'm going to get some rest, now. Go back to sleep now. Thanks."

"Sure."

"No, don't be so casual. You're doing a big thing for me. It's important to me to pass these things on to you people. I'm not going to last much longer."

"Sure, you are."

"No, Lenny."

"Come on."

"No. I was burning as I fell. Remember the alternate radical in the equation I gave you the first night? The field was distorted by the Sun, and the generator restructured the ... " He went on, but I don't remember it. I would have had to remember the original equation for it to make any sense to me, and even if I remembered it I would have had to understand it. This business of reading his equations back to him, see ... that was a trick. Who wants to remember how many grilled cheese sandwiches to go did you sell during the day? I had a wise guy order in double talk, once. I read it back to him like a man running a strip of tape through a recorder, and I wasn't even listening.

"... So you see, Lenny, I'm not going to live. A man in my condition wouldn't survive even in my time and place."

"You're wrong, Buddy. They'll pull you through. They know their business in this place."

"Do you really think so, Lenny?" He whispered it with a sad laugh, if you know what I mean.

"Sure," I said. I was listening to a tanker going by from the north. I could hear the clink of the static chain.

They had brought the man in the next bed in from what they figured was a real bad private plane fire. They said some farmer had seen him falling free, as if he'd jumped without a parachute. They hadn't been able to identify him yet, or find his plane, and he wouldn't give a name. The first two nights he hadn't said a word, until suddenly he said: "Is anybody listening? Is there someone there?"

I had spoken up, and he had asked me about myself—what my name was, what my trouble was. He wanted to know the name of the town, and the nation, and the date—day, month, and year. I told him. I'd seen him in his bandages, during the day, and a man in shape like that, you don't argue about his questions. You answer them. You're glad for the chance to do him a kindness.

He was a smart man, too. He spoke a mess of languages besides English. He tried me in Hungarian for a while, but he knew it a lot better than I did. It's been a long time since I left the folks in Chicago.

I told the nurse, the next day, that he'd been talking to me. The doctors tried to find out who he was and where from, but he didn't talk to them. He convinced them, I think, that he was back in a coma again; they hadn't much believed me when I said he'd talked sensibly at all. After that, I knew better than to tell anybody anything. If he wanted it his way, he was entitled. Except he found out, like I've said, that if he made a sound during the day, they'd give him another needle. You couldn't blame them. It was their way of doing him a kindness.

I lay back, and watched the ceiling begin getting light from the first touch of day outside the windows. Traffic was picking up outside, now. The rigs went by one after another. Farm produce, most likely, catching the market. Lettuce and potatoes, oranges and onions—I could hear the crates shifting on top of each other on the big stake bodies, and the creak of the tie ropes.

"Lenny!"

I answered right away.

"Lenny, the equation for coordinating spacetime is ..." He was in a hurry.

"Yeah." I let it soak into the trick sponge in my mind, and when he asked me to read it back, I squeezed it dry again.

"Thank you, Lenny," he said. I could barely hear him—I began thumbing the night-call bell on the cord draped over the head of my bed.

The next day, there was a new man in the next bed. He was a hunter—a young fellow, from New York—and he'd put a load of birdshot all through his right thigh. It was a couple of days before he wanted to talk, and I didn't get to know him, much.

I guess it was the second or third afternoon after the new man had come in, when my doctor straightened up and pulled the sheet back over my stumps. He looked at me in a peculiar way, and said, offhandedly: "Tell you what, Lenny—suppose we sent you down to surgery and take a little bit more off each of those, hmm?"

"Nuts, Doc, I can smell it, too. Why bother?"

We didn't have much more to say to each other. I lay thinking about Peoria, Illinois, which used to be more fun than it has been lately—for truckers, I mean—and St. Louis and Corpus Christi. I wasn't satisfied with just the Eastern Seaboard anymore. Sacramento, Seattle, Fairbanks and that miserable long run over the Alcan Highway...

In the middle of the night, I was still remembering. I could hear the rigs out on the street, but I was really listening to the sound a Cummins makes going into one of those long switchback grades over the Rockies, and suddenly I turned my head and whispered: "Fellow! Hey, fellow—you awake?" to the new man in the next bed.

I heard him grunt. "What?" He sounded annoyed. But he was listening.

"You ever do any driving? I mean, you ever go down through New Jersey in your car? Well, look, if you ever need a break on tires or a battery, you stop by Jeffrey's Friendly Gas and Oil, on Route 22 in Darlington, and tell 'em Lenny Kovacs sent you. Only watch out—there's a speed trap right outside town, in the summer. ... And if you want a good meal, try the Strand Restaurant, down the street there. Or if you're going the other way, up into New England, you take the Boston Post Road and stop by ... Fellow? You listening?" TR

REVIEWS

SCIENCE FICTION

The Alien Novelist

THE SCIENCE FICTION OF ALGIS BUDRYS, WHO DIED IN JUNE AT THE AGE OF 77, SHOWED THAT THE GENRE CAN PRODUCE LITERARY ART.

By MARK WILLIAMS

If Algirdas Budrys—who signed his work "Algis Budrys" and answered to "Ajay" among the regular Americans with whom he lived—maintained an apprehensive watchfulness toward much of the human race, it wasn't without justification. To start with, as the small son of Lithuania's consul general in Königsberg, East Prussia, he had seen Adolf Hitler pass in full Nazi pomp, while the citizens of the city where Immanuel Kant lay buried whipped themselves into such frenzies of admiration that they soiled themselves and defecated in public.

More than seven decades later, dying in a Chicago suburb, Budrys still remembered what he had seen from the second-story window of his parents' apartment on that spring day in 1936. He told me, "After the *Hitlerjugend* walked through, Hitler came by in an open black Mercedes with his arm propped up. I'm sure he had an iron bar up his sleeve, because he couldn't have kept his arm that particular way for so long otherwise." The Königsberg crowds produced an indescribable sound, Budrys recalled, and some individuals behaved as though experiencing epileptic seizures: men and women rolled on the ground, writhing and clutching at each other—or ran for the bushes as they pulled their underwear down, unable to control their bowels. "Some of them made it, some didn't," he said. "I was only five. It was quite a thing to see." Budrys had spent his earliest years amidst a people who his patriotic Lithuanian parents stressed were not his own; on some evenings, he'd sat on his mother's lap in their darkened apartment while his father sat beside them, holding a loaded pistol in case the brownshirts broke in. But it was on the day he watched the crowds' reaction to Hitler, he wrote later, that he understood that he had come into consciousness among a species of werewolf.

WHO?
by Algis Budrys
1958

ROGUE MOON
by Algis Budrys
1960

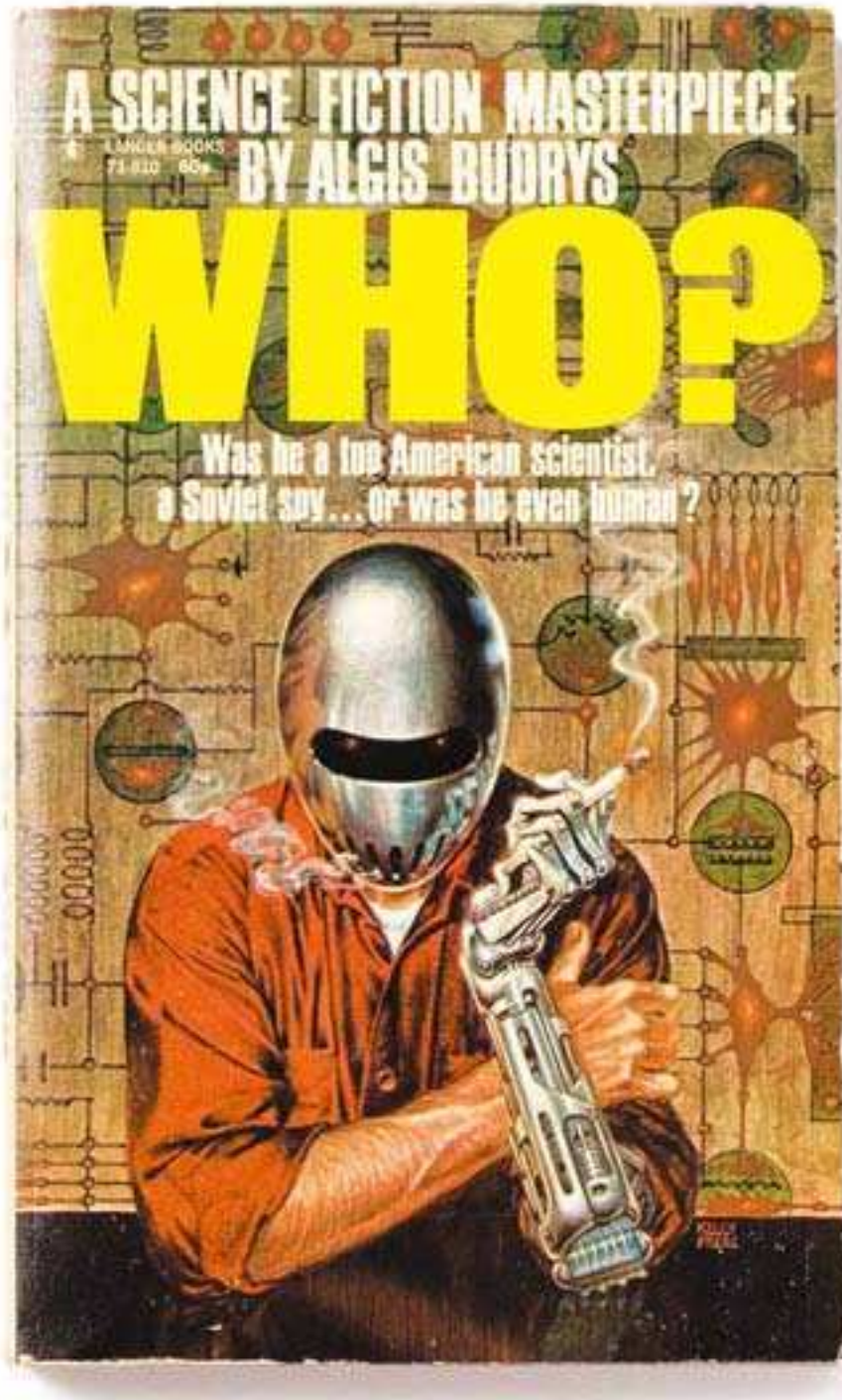
MICHAELMAS
by Algis Budrys
1977

Similar early experiences have compelled others to become writers. Unlike most, Budrys insisted that what he had to say was best articulated in that literary tradition whose principal founding fathers are H. G. Wells, former draper's assistant, and John W. Campbell, MIT dropout and editor of *Astounding Science Fiction* magazine.

This cultured man of Middle European origins—who was multilingual at five, went to university at 16, and as a literary critic was capable of reviewing works as diverse as the stories of the 19th-century German Romantic E. T. A. Hoffmann and a Robert Coover metafiction novel of the 1960s—became a passionate advocate for the view that, amidst all the dreck, great and beautiful work had been published in American science fiction magazines. The fiction Budrys himself began writing as a young man in the 1950s still provides as good evidence as exists that SF can be literary art; at the time, it led his fellow practitioners to regard him as the one among them who was most likely to transform their field into a fully adult literature.

"He was in some ways the best writer of his kind around," the writer, editor, and literary agent Frederik Pohl—at 89, almost the last man left standing from American SF's classical age—told me after Budrys's death in June. "He made sentences come alive better than most writers. I'm not talking just about science fiction writers." This esteem was not confined to his fellow SF authors. Kingsley Amis, the British novelist and critic, once wrote, "Algis Budrys, if all goes well, may become the best science fiction writer since Wells."

That didn't quite happen. In the 1950s and early '60s Budrys published a hundred-odd stories and a half-dozen novels, which reflected his own experience not least in tending to feature deeply isolated people and problems of identity. One novel, *Who?* (1958), had characters as developed as any in that era's serious fiction and compares favorably with work by Budrys's mainstream contemporaries, such as Graham Greene. Budrys capped the decade off with another book, *Rogue Moon* (1960), that knowledgeable readers consider one of the half-dozen



MAN OF STEEL The term "cyborg" wasn't coined till 1960, two years after Budrys published *Who?* Steel-cased prosthetics replacing skull and one arm render the identity of the cyborged scientist in this novel indeterminable.

BOOK PHOTOGRAPHS BY CHRISTOPHER HARTING

SF masterpieces. Then he noted where the science fiction market was going and, because he now had a wife and four children, turned his energies to making money in publishing, editing, and advertising. Through the following decades he kept a foot in the field, mostly with book reviews (he's better known today as science fiction's best critic than as a writer), but his fiction appeared at increasingly longer intervals. Yet some is notable, particularly, the last great novel, *Michaelmas* (1977), which imagines a digitally networked world much like our own.

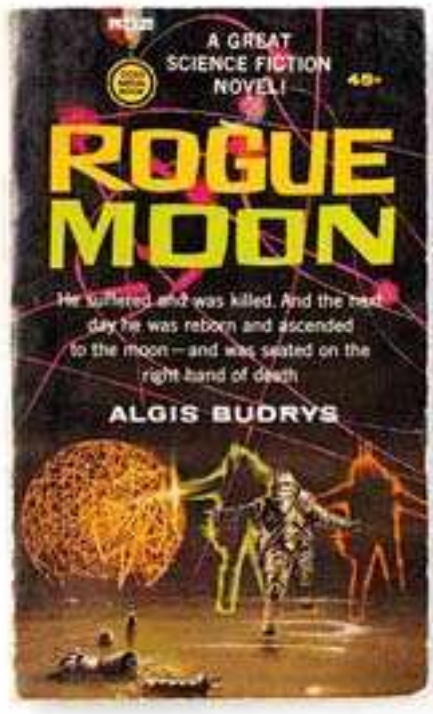
Arguably, there's little real science fiction. That's because drama made relevant by informed social and technological extrapolation and by a profound understanding of the human condition is hard to write. For anyone interested in the real stuff, Budrys was by some lights the best who wrote it. I ran this proposition by Fred Pohl, who has been everything it's possible to be in American science fiction publishing. "I think that's a fair statement," Pohl agreed.

THE GOLDEN AGE OF SCIENCE FICTION

That we have any Budrys books in English is a historical accident: in 1936, when his father failed to get the Paris posting he'd requested, he was assigned to New York instead. Then, in 1940, the USSR occupied Lithuania, which ceased to be an independent state. Budrys's parents, desperate to survive in Depression-era America, ended up running a chicken farm in rural New Jersey. Recalling that farm when I interviewed him this past spring, Budrys chuckled weakly and said, "It was godforsaken." He was enduring the final stages of cancer, a metastatic melanoma; the noises from his oxygen feed line as he struggled to breathe grew more obvious as we talked.

"My big breakthrough came when Miss Anderson, who owned the general store in Dorothy, New Jersey, gave me a bunch of unsold magazines, including *Astonishing Stories*, edited by Frederik Pohl," Budrys said. Having taught himself English at six by reading *Robinson Crusoe*, Budrys had already discovered comic strips like *Flash Gordon* and *Brick Bradford*, then graduated to H. G. Wells's *The Time Machine* and the few remotely science-fictional books in his local library. From *Astonishing*, he moved on to other SF magazines.

In the 1940s, short fiction in magazines constituted Americans' chief medium of home entertainment besides the radio. It was in the cheapest magazines, the pulps, that science fiction had taken root in the United States—most significantly in *Astounding Science Fiction*, which Budrys



MOON SHOT Budrys called writing this novel a "maximum effort." The title was imposed by the publisher, Budrys preferring either *Halt, Passenger*—an inscription he'd seen on a New England gravestone—or *The Death Machine*.

found belatedly, since its covers lacked ray-gun-wielding heroes and big-breasted heroines. "*Astounding* was the last magazine I picked up," he told me. "It didn't look like an SF magazine." *Astounding*'s editor, John W. Campbell, had assembled a stable of writers such as Robert A. Heinlein and Isaac Asimov—all those names who once *were* SF to its readers. Out in the New Jersey hinterlands, the magazine was a revelation to the 11-year-old Budrys: he determined that the vocation of science fiction writer was worth pursuing.

Why did he decide that? "I don't know," he told me. Though he answered my questions courteously, Budrys labored to construct his responses. "I was a writer. I wrote rather well. Like that." Didn't he know how bad the money would be? "I didn't care about the money." When he entered college at 16, had his ambition remained the same? "Yes." And at 21, having sold his first story to Campbell's *Astounding*, what was his creative agenda? Where Budrys had paused for seconds before previous answers, his voice now firmed: "I didn't have any agenda for SF. I just wanted to write it. I thought I was a hotshot." Whom had he thought the best writers? "Me," Budrys answered emphatically.

When I put the phone down I recalled a line near the end of Budrys's first fully achieved novel, *Who?* "For a moment his voice had depth in it, as though he remembered something difficult and prideful he had done in his youth." We had talked a couple more minutes, but it was painfully clear that though Budrys was struggling to behave in a professional manner—much as he'd taken pains to be a good husband and father, dependable friend, and reliable colleague—he was slipping as we talked, struggling to recall things about his own work and finding them gone from memory. Still, he had testified to the main thing: the absolute seriousness of his ambition as an artist who'd been, specifically, a science fiction writer. Three days later he died at home with his family.

To take any science fiction writer seriously is ludicrous, some say, since SF is an inherently juvenile form. Yet the urge to speculate about a technology that could allow us to reach the distant past or future isn't necessarily childish, although an eight-year-old can acquire it from reading *The Time Machine*. To contemplate the future or the past in the spirit of a scientist is to be aware that one's lifetime represents an infinitesimally thin section of the universe's possibilities. Sidney Coleman, the great theoretical physicist (and Budrys's friend and fellow science fiction fan), put it this way: "I assure you, one of the reasons for doing science, especially the kind I do, is that it makes your head feel funny, Goddamned strange. That's also the feeling I get out of SF."

The other main charge against science fiction is that it scants characterization. Here, critics are on firmer ground. The problem, Budrys pointed out, isn't merely that the SF writer must focus heavily on setting at characterization's expense, but also that when unique characters are presented in unique settings, the audience cannot assess what's normal for those characters and what, if anything, their behavior says about the human (or alien) condition. Nevertheless, Budrys said, a meticulous, artful SF writer *can* create fully realized characters.

WHAT SCIENCE FICTION SHOULD BE

Budrys mastered that trick. After a conventional start, his short fiction deepened: a story like "The End of Summer" (1954), for instance, considers the intrinsic limitations of immortality, memory, and identity; "Nobody Bothers Gus" (1955) portrays a lonely superman unlike any in previous SF; and "The Distant Sound of Engines" (first published in 1959, and reprinted on page 77 of this issue) presents a persistent theme: terribly damaged characters who will do anything to survive or leave a legacy.

Who? has a damaged figure at its heart: a scientist named Martino who has been appallingly injured in an explosion at his lab in Europe, near the Soviet border. The Soviets reach him first (the novel extrapolates the Cold War's high-noon years into

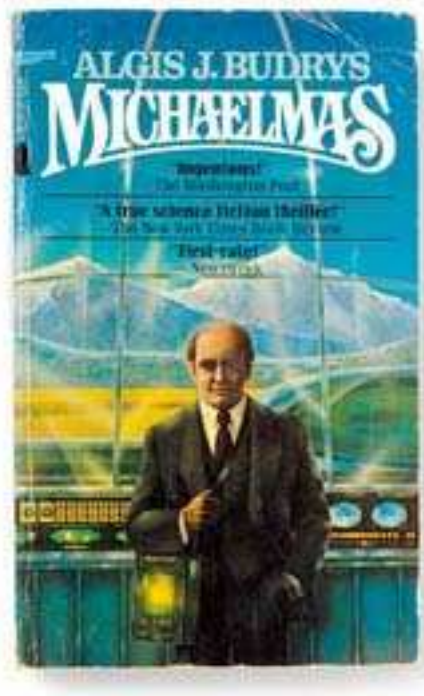
BUDRYS'S PORTRAIT COURTESY OF DAVE BUDRYS

the late 1980s) and rebuild him; when they release a man they say is Martino, cybernetic prosthetics have replaced his face and skull and one arm. Since Martino had been developing a strategically vital technology, why have the Soviets returned him? The problem for an intelligence officer, Rogers, is that if this enigmatic figure is Martino, he must be cleared to work again immediately; if he's an impostor, he must be kept away from the project. In chapters that alternate between Rogers's surveillance of Martino and scenes from Martino's earlier life, *Who?* unfolds in entirely character-driven ways. Budrys imported material from his own life into this novel: Azarin, the Soviet spy chief, is modeled on his father, a former military intelligence officer; the sections describing Martino's youth draw on Budrys's own experience as the son of immigrants. In the end, while technology accounts for the uncertainty about the identity of the man claiming to be Martino, it's his own character—his limited emotional development and his early isolation—that has rendered his claims impossible to corroborate.

Having proved a character-driven SF novel possible, Budrys took a radically different approach with *Rogue Moon*, which takes place in an alternate 1959 where a secret project sponsored by the U.S. government has reached the far side of the moon and found a large, nonnatural structure that kills everybody who enters it. The project of understanding this artifact has fallen to a scientist, Hawks, who has developed a functional matter transmitter—really a matter *duplicator*, since a human subject scanned by Hawks's machine on Earth is destroyed, and the resulting information is used to create one duplicate in the machine and another in a "receiver" on the moon. Crucially, before these duplicates' experiences diverge, they briefly share a consciousness.

Rogue Moon returns to Budrys's themes of identity and memory, adding death and love into the mix. But this brief description gives no sense of the singular flavor of Budrys's text, which conveys only what the characters can see and what they say, without describing their interior mental states. The stylistic antecedents are in the hard-boiled prose of writers like Hemingway and Dashiell Hammett, but such prose had never before been applied to such strange subject matter. Hawks plans to map the lunar artifact by sending duplicates into it; when they die, their cognates on Earth will retain memories of what happened in the preceding moments. Hawks's difficulty is that enduring death by proxy has left each surviving duplicate catatonic. He decides that an abnormal individual might not be driven mad by the experience. A candidate is found: Al Barker, paratrooper, assassin, Olympic ski jumper, mountaineer, and all-around macho man.

TO TAKE ANY SCIENCE FICTION WRITER SERIOUSLY IS LUDICROUS, SOME SAY. YET TO CONTEMPLATE THE FUTURE OR THE PAST IN THE SPIRIT OF A SCIENTIST IS TO BE AWARE THAT ONE'S LIFETIME REPRESENTS AN INFINITESIMALLY THIN SECTION OF THE UNIVERSE'S POSSIBILITIES.



As *Rogue Moon* proceeds, Barker remains functional as his duplicates repeatedly enter the lunar "formation," advance a few meters, and die. The artifact, which may be incomprehensible, isn't really the novel's point. Hawks tells Barker, "Perhaps it's the alien equivalent of a discarded tomato can. Does a beetle know why it can enter the can only from one end as it lies across the trail to the beetle's burrow?" The novel focuses on the aims and relationships of its characters, who are, the reader grasps, all psychopaths: Hawks will do anything to achieve his aims, Barker is hollow, and so on.

Hawks is capable of softer emotions, however, which provide the novel with its highly original conclusion. The scientist meets a young woman, with whom he opens up. At the novel's end, as a Barker duplicate undertakes the final trip that will reach the artifact's far side, a Hawks duplicate joins him. They emerge alive, but Hawks tells Barker that there's no life for them on Earth—that belongs to their duplicates—and walks off to die alone on the moon's surface. In the book's final lines, the Hawks on Earth finds a note in his hand "and read the blurred message with little difficulty, since it was in his own writing, and, in any case, he knew what it said. It was: 'Remember me to her.'"

Budrys wrote one more significant novel, *Michaelmas*. Its hero, Laurent Michaelmas, is ostensibly a wealthy, middle-aged news anchorman; 20 years before, however, he was a countercultural computer hacker who wrote a program, Domino, that's since grown into a sentient artificial intelligence distributed throughout the planet's digital networks. Domino empowers Michaelmas to be the world's hidden manager.

The theme of identity recurs. An astronaut believed dead is resurrected—he's a copy, of course—and Michaelmas, too, meets a replica of himself. Four features distinguish *Michaelmas*. First, it is the most polished example of Budrys's craft: the language is highly literary—striking metaphors and similes abound—and the narrative voice swoops imperceptibly from third person past to first person present; wonderful characters—an Ossetian cosmonaut, an aging newsman, a Turkish limousine chauffeur, and many others—are painted in quick, deft strokes; and the plot gallops across a single, eventful day and three continents. Second, there's Michaelmas himself: absolute power corrupts absolutely, in Lord Acton's phrase, and great men are nearly always bad men; yet Michaelmas is secretly a great man who remains benevolent and uncorrupted. Third, there's the persistent underlying note of melancholy: mourning his decades-dead wife, Michaelmas has no affectionate relationships other than the one with his creation, Domino; and our universe, it turns out, is just a fluke of information theory, tuned into existence by beings who themselves may be only drifting particles elsewhere in the multiverse.

Finally, there's the fact that *Michaelmas* depicts a near future that's now an alternative version of our immediate past. In many ways, it's a more attractive world, with a U.N. manned mission to the solar system's outer planets and less terrorism, war, and crime. In a similar way, it could be argued, Budrys's science fiction presents an alternative version of the genre—a promise of better possibilities that were never quite realized. Indeed, the bulk of Budrys's writing was published a half-century ago and isn't in print, though it's easily obtainable from online booksellers or brick-and-mortar secondhand stores. You should make the effort. This is what science fiction can be but hardly ever is. TR

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COLLABORATION

Wikipedia and the Meaning of Truth

WHY THE ONLINE ENCYCLOPEDIA'S EPISTEMOLOGY SHOULD WORRY THOSE WHO CARE ABOUT TRADITIONAL NOTIONS OF ACCURACY.

By SIMSON L. GARFINKEL

With little notice from the outside world, the community-written encyclopedia Wikipedia has redefined the commonly accepted use of the word "truth."

Why should we care? Because Wikipedia's articles are the first- or second-ranked results for most Internet searches. Type "iron" into Google, and Wikipedia's article on the element is the top-ranked result; its article on the Iron Cross is also first. Google's search algorithms rank a story in part by how many times it has been linked to; people are linking to Wikipedia articles *a lot*.

This means that the content of these articles really matters. Wikipedia's standards of inclusion—what's in and what's not—affect the work of journalists, who routinely read Wikipedia articles and then repeat the wiki-claims as "background" without bothering to cite them. These standards affect students, whose research on many topics starts (and often ends) with Wikipedia. And since I used Wikipedia to research large parts of this article, these standards are affecting you, dear reader, at this very moment.

Many people, especially academic experts, have argued that Wikipedia's articles can't be trusted, because they are written and edited by volunteers who have never been vetted. Nevertheless, studies have found that the articles are remarkably accurate. The reason is that Wikipedia's community of more than seven million registered users has organically evolved a set of policies and procedures for removing untruths. This also explains Wikipedia's explosive growth: if the stuff in Wikipedia didn't seem "true enough" to most readers, they wouldn't keep coming back to the website.

These policies have become the social contract for Wikipedia's army of apparently insomniac volunteers. Thanks to them, incorrect information generally disappears quite quickly.

So how do the Wikipedians decide what's true and what's not? On what is their epistemology based?

Unlike the laws of mathematics or science, wikitruth isn't based on principles such as consistency or observability. It's not even based on common sense or first-hand experience. Wikipedia has evolved a radically different set of epistemological standards—standards that aren't especially

RAYMOND BEISINGER

surprising given that the site is rooted in a Web-based community, but that should concern those of us who are interested in traditional notions of truth and accuracy. On Wikipedia, objective truth isn't all that important, actually. What makes a fact or statement fit for inclusion is that it appeared in some other publication—ideally, one that is in English and is available free online. "The threshold for inclusion in Wikipedia is verifiability, not truth," states Wikipedia's official policy on the subject.

Verifiability is one of Wikipedia's three core content policies; it was codified back in August 2003. The two others are "no original research" (December 2003) and "neutral point of view," which the Wikipedia project inherited from Nupedia, an earlier volunteer-written Web-based free encyclopedia that existed from March 2000 to September 2003 (Wikipedia's own NPOV policy was codified in December 2001). These policies have made Wikipedia a kind of academic agora where people on both sides of politically charged subjects can rationally discuss their positions, find common ground, and unemotionally document their differences. Wikipedia is successful because these policies have worked.

WIKIPEDIA'S REFERENCE POLICY
en.wikipedia.org/wiki/Wikipedia:Verifiability

WIKIPEDIA'S "NO ORIGINAL RESEARCH" POLICY
en.wikipedia.org/wiki/Wikipedia:No_original_research

WIKIPEDIA'S "NEUTRAL POINT OF VIEW" POLICY
en.wikipedia.org/wiki/Wikipedia: Neutral_point_of_view

WIKIPEDIA'S POLICY ON RELIABILITY OF SOURCES
en.wikipedia.org/wiki/Wikipedia:Reliable_sources

WIKIPEDIA'S CITATION POLICY
en.wikipedia.org/wiki/Wikipedia:Citing_sources

Unlike Wikipedia's articles, Nupedia's were written and vetted by experts. But few experts were motivated to contribute. Well, some wanted to write about their own research, but Larry Sanger, Nupedia's editor in chief, immediately put an end to that practice.

"I said, 'If it hasn't been vetted by the relevant experts, then basically we are setting ourselves up as a frontline source of new, original information, and we aren't set up to do that,'" Sanger (who is himself, ironically or not, a former philosophy instructor and by training an epistemologist) recalls telling his fellow Nupedians.

With experts barred from writing about their own work and having no incentive to write about anything else, Nupedia struggled. Then Sanger and Jimmy Wales, Nupedia's founder, decided to try a different policy on a new site, which they launched on January 15, 2001. They adopted the newly invented "wiki" technology, allowing *anybody* to contribute to any article—or create a new one—on any topic, simply by clicking "Edit this page."

Soon the promoters of oddball hypotheses and outlandish ideas were all over Wikipedia, causing the new site's volunteers to spend a good deal of time repairing damage—not all of it the innocent work of the misguided or deluded. (A study recently published in *Communications of the Association for Computing Machinery* found that 11 percent of Wikipedia articles have been vandalized at least once.) But how could Wikipedia's volunteer editors tell if something was true? The solution was to add references and footnotes to the articles, "not in order to help the reader, but in order to establish a point to the satisfaction of the [other] contributors," says Sanger, who left Wikipedia before the verifiability policy was formally adopted. (Sanger and Wales, now the chairman emeritus of the Wikimedia Foundation, fell out about the scale of Sanger's role in the creation of Wikipedia. Today, Sanger is the creator and editor in chief of Citizendium, an alternative to Wikipedia that is intended to address the inadequacy of its "reliability and quality.")

Verifiability is really an appeal to authority—not the authority of truth, but the authority of other publications. Any other publication, really. These days, information that's added to Wikipedia without an appropriate reference is likely to be slapped with a "citation needed" badge by one of Wikipedia's self-appointed editors. Remove the badge and somebody else will put it back. Keep it up and you might find yourself face to face with another kind of authority—one of the English-language Wikipedia's 1,500 administrators, who have the ability to place increasingly restrictive protections on contentious pages when the policies are ignored.

To be fair, Wikipedia's verifiability policy states that "articles should rely on reliable, third-party published sources" that themselves adhere to Wikipedia's NPOV policy. Self-published articles should generally be avoided, and non-English sources are discouraged if English articles are available, because many people who read, write, and edit En.Wikipedia (the English-language version) can read only English.

MOB RULES

In a May 2006 essay on the technology and culture website Edge.org, futurist Jaron Lanier called Wikipedia an example of "digital Maoism"—the closest humanity has come to a functioning mob rule.

Lanier was moved to write about Wikipedia because someone kept editing his Wikipedia entry to say that he was a film director. Lanier describes himself as a "computer scientist, composer, visual artist, and author." He is good at all those things, but he is no director. According to his essay, he made one short experimental film in the 1990s, and it was "awful."

"I have attempted to retire from directing films in the alternative universe that is the Wikipedia a number of times, but somebody always overrules me," Lanier wrote. "Every time my Wikipedia entry is corrected, within a day I'm turned into a film director again."

Since Lanier's attempted edits to his own Wikipedia entry were based on firsthand knowledge of his own career, he was in direct violation of Wikipedia's three core policies. He has a point of view; he was writing on the basis of his own original research; and what he wrote couldn't be verified by following a link to some kind of legitimate, authoritative, and verifiable publication.

Wikipedia's standard for "truth" makes good technical and legal sense, given that anyone can edit its articles. There was no way for Wikipedia, as a community, to know whether the person revising the article about Jaron Lanier was really Jaron Lanier or a vandal. So it's safer not to take people at their word, and instead to require an appeal to the authority of another publication from everybody who contributes, expert or not.

An interesting thing happens when you try to understand Wikipedia: the deeper you go, the more convoluted it becomes. Consider the verifiability policy. Wikipedia considers the "most reliable sources" to be "peer-reviewed journals and books published in university presses," followed by "university-level textbooks," then magazines, journals, "books published by respected publishing houses," and finally "mainstream newspapers" (but not the opinion pages of newspapers).

Once again, this makes sense, given Wikipedia's inability to vet the real-world identities of authors. Lanier's complaints when his Wikipedia page claimed that he was a film director couldn't be taken seriously by Wikipedia's "contributors" until Lanier persuaded the editors at *Edge* to print his article bemoaning the claim. This *Edge* article *by* Lanier was enough to convince the Wikipedians that the Wikipedia article *about* Lanier was incorrect—after all, there was a clickable link! Presumably the editors at *Edge* did their fact checking, so the wikiworld could now be corrected.

As fate would have it, Lanier was subsequently criticized for engaging in the wikisin of editing his own wikientry. The same criticism was leveled against me when I corrected a number of obvious errors in my own Wikipedia entry.

"Criticism" is actually a mild word for the kind of wikijustice meted out to people who are foolish enough to get caught editing their own Wikipedia entries: the entries get slapped with a banner headline that says "A major contributor to this article, or its creator, may have a *conflict of interest* regarding its subject matter." The banner is accompanied by a little picture showing the scales of justice tilted to the left. Wikipedia's "Autobiography" policy explains in great detail how drawing on your own knowledge to edit the Wikipedia entry about yourself violates all three of the site's cornerstone policies—and illustrates the point with yet another appeal to authority, a quotation from *The Hitchhiker's Guide to the Galaxy*.

But there is a problem with appealing to the authority of other people's written words: many publications don't do any fact checking at all, and many of those that do simply call up the subject of the article and ask if the writer got the facts wrong or right. For instance, Dun and Bradstreet gets the information for its small-business information reports in part by asking those very same small businesses to fill out questionnaires about themselves.

"NO ORIGINAL RESEARCH"

What all this means is hard to say. I am infrequently troubled by Wiki's unreliability. (The quality of the writing is a different subject.) As a computer scientist, I find myself using Wikipedia on a daily basis. Its discussions of algorithms, architectures, microprocessors, and other technical subjects are generally excellent. When they aren't excellent and I know better, I just fix them. And when they're wrong and I don't know better—well, I don't know any better, do I?

I've also spent quite a bit of time reviewing Wikipedia's articles about such things as the "Singularity Scalpel," the "Treaty of Algeron," and "Number Six." Search for these terms and you'll be directed to Wikipedia articles with the titles "List of *Torchwood* items" and "List of treaties in *Star Trek*," and to one about a Cylon robot played by Canadian actress Tricia Helfer. These articles all hang their wikiexistence upon scholarly references to original episodes of *Dr. Who*, *Torchwood*, *Star Trek*, and *Battlestar Galactica*—popular television shows that the Wikipedia contributors dignify with the word "canon."

I enjoy using these articles as sticks to poke at Wikipedia, but they represent a tiny percentage of Wikipedia's overall content. On the other hand, they've been an important part of Wikipedia culture from the beginning. Sanger says that early on, Wikipedia made a commitment to having a wide variety of articles: "There's plenty of disk space, and as long as there are people out there who are able to write a decent article about a subject, why not let them? ... I thought it was kind of funny and cool that people were writing articles about every character in *The Lord of the Rings*. I didn't regard it as a problem the way some people do now."

What's wrong with the articles about fantastical worlds is that they are at odds with Wikipedia's "no original research" rule, since almost all of them draw their "references" from the fictions themselves and not from the allegedly more reliable secondary sources. I haven't nominated these articles for speedy deletion because Wikipedia makes an exception for fiction—and because, truth be told, I enjoy reading them. And these days, most such entries are labeled as referring to fictional universes.

So what is Truth? According to Wikipedia's entry on the subject, "the term has no single definition about which the majority of professional philosophers and scholars agree." But in practice, Wikipedia's standard for inclusion has become its de facto standard for truth, and since Wikipedia is the most widely read online reference on the planet, it's the standard of truth that most people are implicitly using when they type a search term into Google or Yahoo. On Wikipedia, truth is received truth: the consensus view of a subject.

That standard is simple: something is true if it was published in a newspaper article, a magazine or journal, or a book published by a university press—or if it appeared on *Dr. Who*. TR

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THE INTERNET

iTube

WHY 23,201 PEOPLE CARE THAT JUSTINE EZARIK JUST ATE A COOKIE.

By EMILY GOULD

Twenty-four-year-old Justine Ezarik, who goes by the moniker "iJustine," is bouncing around on my computer screen in a pink tank top and black bra, her platinum hair—ordinarily perfectly straight—increasingly mussed as she works herself into a frenzy about something. I have turned my computer's sound off, so I don't know what's making her widen her heavily made-up eyes, flail her head from side to side, and fix the camera with an open-mouthed pout. My boyfriend glances at my screen as he walks by—and stops in his tracks and watches.

iJUSTINE
www.youtube.com/user/ijustine
www.justin.tv/ijustine

"When is she going to take her top off?" he says after a minute.

A few days later, on the phone from her new home in L.A., Ezarik tells me that women who work "in technology" are at a disadvantage: "People don't want to take us seriously." Her chirpy voice is familiar from the video (which turned out to be about a frustrating exchange with a prissy waiter who tried to steer her away from ordering a cheeseburger). "Like, speaking on panels, people don't want to take you seriously. I've been in technology all my life. Like, I was the only girl in my computer science classes in high school. That's why a lot of younger girls look up to me now, because they want to do this stuff and use it to its full potential."

By "this stuff," Ezarik means video blogging about gadgets and social-networking sites, not widening your eyes and yelping with delight and making sure your cleavage is in frame. But you'd have to be even wider-eyed than iJustine to believe that those latter skills, impediments to being taken seriously on panels though they may be, haven't contributed to stardom in new media.

For iJustine *is* a star: a week after that cheeseburger video was posted, it had been viewed more than 600,000 times on YouTube. That's nothing compared with the more than 1,336,000 views generated by the most famous of her 168 YouTube videos, "iPhone bill." (In iJustine's masterwork, which like most of her oeuvre takes a little over a minute to consume, she simply flips through her hefty 300-page phone bill, exasperated.) Her channel iJustine.tv on the two-year-old user-generated-video site Justin.tv, where for six months she wore camera equipment and "lifecast" 24 hours a day, seven days a week, is still one of that site's most popular.

Ezarik is one of a new breed of completely self-constructed celebrities. Like my friend Julia Allison, whose online self-promotion recently landed her on the cover of *Wired,* she is a Web 2.0 version of the American everygirls with bleached teeth and fake tans who have enjoyed reality-show notoriety for a decade. But Ezarik didn't wait around for a reality show to cast her: she trained the camera on herself, controlling every aspect of how she was portrayed. And while her shtick is that she's just putting quotidian stuff online, she's actually as invested as a reality-show producer in shaping and policing a brand. "I feel like iJustine has become sort of like this character," she explains. "It's not like I don't drink or go out and do stuff, but I won't drink on camera, and if I swear I'll bleep it out. I really try to keep it clean. I kind of think if my grandmother won't like it I won't do it, 'cause she's probably one of my biggest fans."

Justin.tv helped make Justine Internet famous. Ezarik has been a professional (albeit one who hastens to say, "Put that in quotes: 'professional!'") video blogger for the past two and a half years, but her celebrity got a boost when she approached Justin.tv founder Justin Kan at last year's Macworld conference. "He was wearing a camera strapped to his head, and I was like, 'What is that?'" she says. She says she asked to try the camera out, after which she and Kan decided that she would either wear the camera or be on camera all the time—with exceptions for the bathroom and meetings—

for the next six months, becoming what she calls a "beta tester" for Justin.tv. (She was never paid by the site, which makes money by embedding ads in and around its user-generated—that is, free—content.)

By now, Justine has reduced her lifecasting to a few hours per week. (Justin.tv is now leaning away from it, too: "In our experience, there are less broadcaster-intensive uses—cases that produce more interesting content for the end user," Justin.tv CEO Michael Seibel obscurely explained in an e-mail.) In part, this is simply because Ezarik needs Justin.tv less than she once did: she has 50,000 MySpace friends, she long ago reached her limit of 5,000 Facebook friends, and she has about 23,000 Twitter followers. Two hours ago she informed them that she was "LOL"ing. Twenty hours earlier, she was eating a "really good cookie."

"I AM THE INTERNET" IS THE TAG LINE OF iJUSTINE'S YOUTUBE CHANNEL, AND WHEN I FIRST SAW IT, I WAS *OFFENDED ON THE INTERNET'S BEHALF.*

Ezarik backed away from lifecasting—well, for a lot of reasons. She says she quickly became immune to the nastier anonymous online comments, but she did feel sorry for friends who would stumble into the frame and wind up as collateral damage—mocked or, worse, vetoed by her viewers. "Someone e-mailed and was like, 'We're going to have to vote [a friend] off your show,'" she says. "And I was like, 'Actually it's not a show; actually, this is just my life.'"

But was iJustine.tv really just Justine's life? Explaining how lifecasting has led her to new opportunities—like a series of video advertisements, to appear on AT&T's website, that she's just finished shooting in Alaska—Ezarik describes how living under constant scrutiny helped her hone her dramatic skills: "I had to be 'on' at all times. It was kind of like a résumé-building experience. I mean, I wasn't acting, but I kind of was."

This *kind-of-acting* is all over YouTube, and if you haven't seen it, it's hard to describe. Women like Justine seem to be imitating hot-yet-funny comedian-actresses like Chelsea Handler and Anna Faris, making goofy expressions and doing silly voices. Unlike those comedians, however, they're looking at their own reflections in the camera's viewfinder and posing ceaselessly, the way you do when you look in a mirror. But it's hard—maybe impossible!—to be funny when you're worried about looking pretty. Justine compensates for her unfunniness with bug-eyed, squealing enthusiasm. Wheeee! She's chased down an ice-cream truck! Eeeek! She found an Apple store with the new iPhone in stock! Oooooh! Yes, she is finally, ohmygod, going to get her glossy lips around a cheeseburger! Yay!

In an era when fame has never been less likely to guarantee fortune, it seems fair to ask Ezarik what keeps her in cheeseburgers. Specifically, does she receive endorsement money from Apple, whose products she promotes obsessively? (She's the first person in months from whom I've received an e-mail with the "Sent from my iPhone" auto-signature attached. I was reminded of a former coworker who, the day after the iPhone's release, changed his signature to read, "Sent from my iPhone, yeah, I have one, no big deal.") "Everyone's like, 'They pay you. They pay you,'" she says. "My manager's like, please stop promoting Apple so much. Maybe one day—that's what I'm hoping for," she says with a laugh. But for now, while she and her manager—a man named Richard Frias, whose other clients include the YouTube celebrities HappySlip and KevJumba—await that Apple endorsement deal, she makes her money by appearing at conferences and in online promotional spots, and dreams of becoming *really* famous, like on TV or in movies.

She's delighted to have moved from Pittsburgh to L.A., she says: "There are so many more projects. It's a lot easier having someone else shoot and edit for you." But while lifecasting has paid off for Ezarik career-wise, it's also had its downside, life-wise. For starters, maintaining contact with her growing fan base has become a major time suck. Fresh off the plane from Alaska—the first thing she mentions about the trip is how slow the Internet access was there—Ezarik's got a backlog of thousands of e-mails in her in-box. From her mail, she's concluded that her fans are mostly between 11 and 18, and that they're about half male and half female—which is "surprising," she says, because "when you think of technology and the Internet, you think of guys." At a fair in Alaska, Ezarik bumped into one of the young male fans, who was overwhelmed. "He was, like, shaking," she says. "He was like, 'Are you—are you iJustine?' I was like, 'It'll be okay.'"

And then there's what Ezarik calls "the stalker stuff," which has subsided but is still a factor. "I try not to publicize the stalker stuff, because I don't want them to know they're getting to me," she says, but she allows that people call her parents' house "all the time." "I'm lucky to be alive," she says more than once, and each time she says it, the light, chipper tone of her voice doesn't alter. She could just as easily be talking about a new iPhone app.

Still, this is the first response I've gotten from Ezarik that hasn't sounded somewhat coached or canned, and it emboldens me to ask her, point-blank, whether she likes the attention. She pauses a moment, then deftly parries. "I don't hate it," she deadpans. "What I like the most about everything is the community of people I've brought together. When I was lifecasting, I was a way for people to connect. It wasn't even about me. I was sitting there doing nothing, and people were having conversations about politics and their life. And it was kind of cool to see that."

One last question: does Ezarik consider herself a feminist? "I try to keep everything very clean so other women don't feel like they have to use sex to sell," she replies, and then goes on in that vein. Apparently,

the conversation about Judith Butler and gender as performance will have to wait for another day.

Still, when we hang up so that Ezarik can start chipping away at her in-box, I think about how well she answered my question about attention. Attention's a touchy subject right now. As we trust cultural arbiters less and less to tell us who deserves attention, calling those who seek it—especially women—attention whores has become a dismissive, silencing insult. But here's the thing: understanding that your blog is less a shrine to your awesomeness and more a location where a like-minded community can form—and genuinely being *okay* with that—is actually pretty rare, even among Internet personalities. iJustine's willingness to let her fans share her spotlight, even as she mugs for the camera, might be what's really helping her rack up all those page views.

So maybe I should be taking Justine Ezarik more seriously, or at least not dismissing her for being blonde and photogenic, and knowing it and using it to her advantage. Certainly, I find the persona she's crafted cloying; but then, I'm not the intended audience. For the Twittering 16-year-old who lives for gadgets, though ... well, it's easy to see why he'd quake in her presence.

"I am the Internet" is the tag line of iJustine's YouTube channel, and when I first saw it, I was *offended on the Internet's behalf*. It didn't seem fair that this girl was getting so much attention for providing her fans with a steady stream of Twittered fake intimacies—"Eating chocolate-covered pretzels"; "I don't like time zones!!"—and cutesy videos. The idea that she was somehow representative of all of us online was galling.

The great thing about the Internet, though, is that it isn't about to run out of bandwidth. iJustine is the Internet, sure, but so are you, if you want. There's no reason—centuries of cultural conditioning aside—why you couldn't do things differently. TR

EMILY GOULD WAS AN EDITOR AT GAWKER.COM FROM SEPTEMBER 2006 TO NOVEMBER 2007. SHE WROTE ABOUT WALTER BENJAMIN IN THE SEPTEMBER/OCTOBER ISSUE OF *TECHNOLOGY REVIEW*.

A RFID CHIP

Nohl and Starbug used acetone to peel the plastic off the card's millimeter-square chip. Once they isolated the chip, they embedded it in a block of plastic and sanded it down layer by layer to examine its construction. Nohl compares this to looking at the structure of a building floor by floor.

An acetone bath exposes this smart card's chip.

How Smart Is a Smart Card?

BY EXTRACTING THE RFID CHIP FROM A SMART CARD, IT'S POSSIBLE TO LEARN MUCH ABOUT THE ALGORITHMS THAT CONTROL IT.

By ERICA NAONE

LAYERS

The chip has multiple layers that perform different functions, which the researchers had to tease apart in order to identify and understand its algorithms. Since the sanding technique didn't work perfectly, it produced a series of partial images. Nohl and Starbug borrowed techniques from panoramic photography to create a clear composite image of each layer. They identified six in all: a cover layer, three interconnection layers, a logic layer, and a transistor layer.

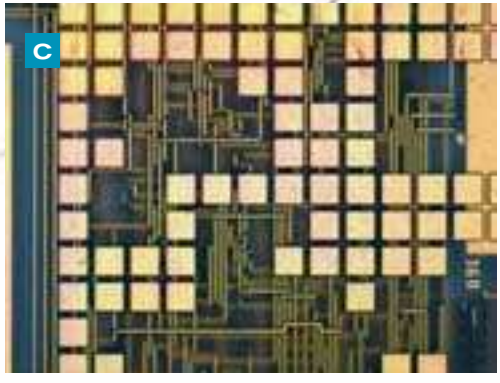
WAVING A SMART CARD in front of a radio frequency identification (RFID) reader can provide access to buildings, pay for subway rides, and even initiate credit-card transactions. With more than a billion units sold, the NXP Mifare Classic RFID tag is the most commonly used smart-card chip; it can be found in the London subway system's Oyster card, Australia's SmartRider, and the Boston subway's Charlie Card. Security researcher Karsten Nohl, who recently got his PhD in computer science from the University of Virginia, and "Starbug," a member of a Berlin hacker group called the Chaos Computer Club, hacked into a Mifare Classic's hardware to gain insight into its cryptographic algorithms. After analyzing the chip, Nohl questioned its security in a series of presentations at recent conferences, including Black Hat in Las Vegas.

CHRISTOPHER HARTING

B

B LOGIC AND TRANSISTOR LAYERS

A close look at these layers reveals about 10,000 groups of transistors, which execute the algorithms that run the chip. Nohl and Starbug's analysis revealed that each group performs one of 70 logic functions, and that the groups are repeated in different patterns.

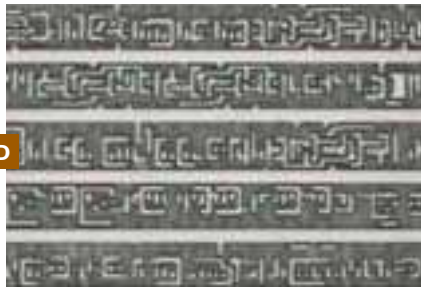


C

A

C INTERCONNECTION LAYERS

Several layers of metal between the protective cover layer and the logic layer provide the connections between the different logic functions. Wires running through them control the flow of current through the groups of transistors.



D

D LOGIC GATES

The groups of transistors that perform the chip's logical operations are known as logic gates. By analyzing the pattern of logic gates on the chip, the researchers determined which circuits performed which functions; for example, a string of one-bit memory cells known as flip-flops pointed to the part of the chip responsible for cryptography. The researchers made a map of the logic gates and the connections between them, which allowed them to uncover the chip's cryptographic algorithm and determine that it was weak. Nohl says that RFID security could be improved by the use of stronger, peer-reviewed algorithms, along with measures to obscure or tamper-proof the circuit itself.

WWW See a smart card being disassembled step by step: **technologyreview.com/hack**

Fuel-Cell Power-Up

A NEW PROCESS INCREASES THE ENERGY OUTPUT OF METHANOL FUEL CELLS BY 50 PERCENT.

By KRISTINA GRIFANTINI

PORTER GIFFORD

In her lab at MIT, chemical-engineering professor Paula Hammond pinches a sliver of what looks like thick Saran wrap between tweezers. Though it appears unremarkable, this polymer membrane can significantly increase the power output of a methanol fuel cell, which could make that technology suitable as a lighter, longer-lasting, and more environmentally friendly alternative to batteries in consumer electronics such as cell phones and laptops.

Methanol is a promising energy source for fuel cells because it is a liquid at room temperature, so it's easier to manage than hydrogen. But so far, its commercial applications have been limited. One reason has to do with the properties of the proton-conducting membranes at the heart of fuel-cell technology.

On one side of a methanol fuel cell, a catalyst causes methanol and water to react, yielding carbon dioxide, protons, and free electrons. The protons pass through a membrane to a separate compartment, where they combine with oxygen from air to form water. The electrons, which can't cross the membrane, are forced into wires, generating a current that can be used to power electronic devices.

The more protons cross the membrane, the more power is generated. But the polymers that conduct protons well also tend to let the methanol solution into the other compartment. The resulting loss of fuel lowers the cells' power output. To limit such "methanol crossover," researchers have to either use polymers that don't conduct protons as well or make thicker membranes. But both of those options decrease efficiency, too.

In work published last spring in *Advanced Materials,* Hammond used an elegant, inexpensive process to reduce methanol crossover in a commercial fuel-cell membrane, increasing the efficiency of a methanol fuel cell by more than 50 percent. "What we've done is generate a very thin film that actually prevents the permeation of methanol but at the same time allows a rapid rate of proton transport," says Hammond. Encouraged by this success, her team is now working to build such membranes from scratch, which could make them less expensive.

A MODIFIED PROCESS

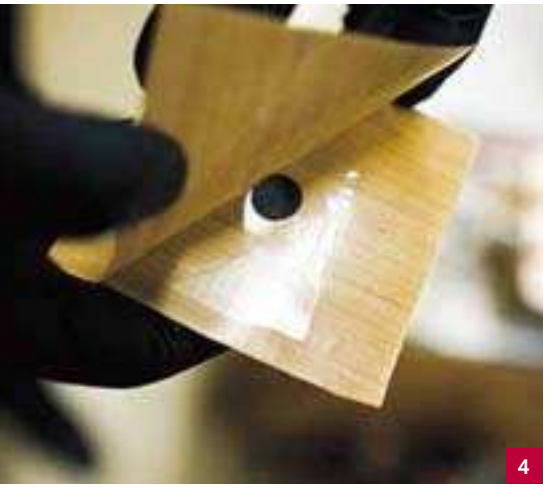
A layer-by-layer assembly technique is the key to Hammond's membranes. In earlier work, her team altered a membrane made of Nafion, a polymer manufactured by DuPont that is commonly used in fuel cells. It con-

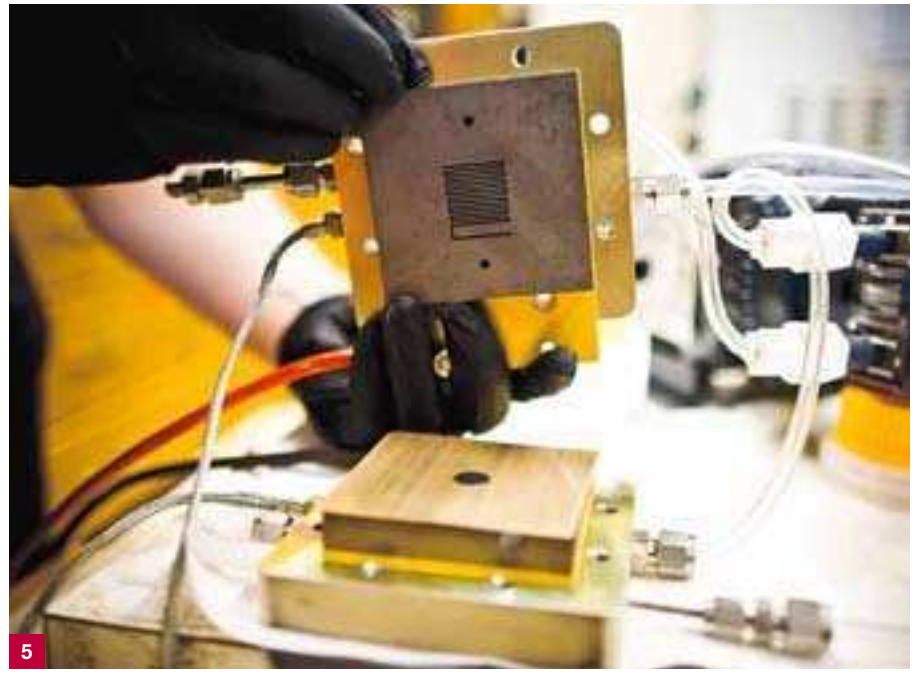
Left: Paula Hammond holds a piece of a fuel-cell membrane made using a layer-by-layer assembly technique. This method allows her to produce membranes that increase the power output of methanol fuel cells, making them more viable as an alternative to batteries for small electronics such as cell phones. **1.** The process begins with a specially treated silicon disc, which a researcher attaches to a rotating stand in a fume hood. An automated sprayer system emits fine mists of two different polymers and a water solution in a sequence repeated several hundred times in a few hours. **2.** When the membrane is finished, a researcher gently peels it off and cuts it to size for testing. **3.** A researcher sets the membrane in a device that can measure resistance and places it in a humidity chamber. In the chamber, tests are carried out to determine how efficiently protons can pass through the membrane.

ducts protons well but also permits some methanol leakage, and it's relatively expensive to make.

To begin the new process, Avni Argun, a postdoc in the lab and lead author on the *Advanced Materials* paper, mounts a specially treated silicon disc in a lab hood and starts the disc slowly rotating. Facing the membrane are four sprayer nozzles. Each nozzle is connected to a separate container. One contains a positively charged polymer solution and one a negatively charged polymer solution; two hold water.

Argun starts the sprayer system, which mists the disc with the positive solution for a few seconds, then with a water rinse, then with the negatively charged polymer, and finally with water again. A two-layer film forms within about 50 seconds. The thickness of this "bilayer" depends on the polymers and can range from 3 to 50 nanometers. In about six hours, the sprayer can apply between 400 and 600 bilayers, creating a membrane about 20 micrometers thick. The membrane described in *Advanced Materials* was made up of three bilayers on top of a Nafion membrane, adding only 260 nanometers to its thickness. By using a combination of positive and negative polymers, the researchers maintained





4. If the membrane conducts protons well, a researcher prepares to test it in a fuel cell, placing it between two small, black, circular electrodes. A hot press is then used to seal them inside a square insulating gasket.
5. The researcher puts the membrane-electrode assembly in a fuel cell, between two graphite blocks. The blocks contain small channels that distribute methanol and air through the cell. Hammond's team then measures the fuel cell's efficiency under various conditions.

Nafion's high conductivity while reducing its methanol crossover.

Other researchers have tried to reduce membrane permeability by using new polymers or blending two different polymers. Blending often doesn't work well, though, because polymers with different structures tend to separate, making the membrane less stable. With the layer-by-layer assembly process—common in other areas of materials science—"we combine two different materials, but on a nanometer-length scale so they're really intermingled," Hammond says.

TESTING GROUNDS

After the membrane dries, Argun carefully peels it off the disc and tests its permeability and electrical resistance, which allows him to calculate its conductivity. With a large clip, he fastens the membrane between a plastic chip and a base that holds platinum wires that will measure resistance. After putting the assembly in a sealed plastic box that allows him to control temperature and humidity, he manipulates the membrane using a pair of gloves that reach through the box and into the chamber. Most membranes perform better under high temperature and humidity, so both conditions must be noted. Argun connects the assembly to an external analyzer to test the membrane's resistance. Measuring its permeability is more straightforward; he simply notes the amount of methanol that diffuses through it over a specific amount of time.

If a membrane fares well in these initial tests, Argun couples it to a positive and a negative electrode (where the electricity-producing reactions take place) to see how it would perform in an actual fuel cell. He places the electrodes—two black, circular carbon cloths studded with particles of platinum and a metal alloy—on either side of the membrane. Then he sandwiches the whole apparatus inside an insulating gasket that looks like thin cardboard. Finally, he seals the unit using a hot press.

Graduate student Nathan Ashcraft takes over from here. Ashcraft puts the membrane-electrode assembly into an active fuel cell, into which air and methanol are carefully pumped. Two square slabs of steel, about the size of slices of bread, make up the outside of the cell; they contain heaters that allow Ashcraft to precisely control the temperature of the reaction. Between the steel slabs, two gold-plated electrodes sandwich graphite blocks with small channels etched into them. Ashcraft places the membrane-electrode assembly between the blocks and secures it with screws. He then pumps methanol and air through the channels to either side of the assembly. He measures and records the resulting current, along with the system's temperature.

Hammond's team has not yet devised a completely new membrane that conducts as well as Nafion. However, "we feel like we're very close," she says. The team is also experimenting with membrane thickness; if a membrane is too thin, it will tear in the fuel cell, but thicker membranes don't conduct protons as well. The membrane that the lab ends up with will probably be about 50 micrometers thick, Ashcraft says. Hammond also plans to try building membranes that incorporate additional polymers. TR

WWW Paula Hammond on how her membranes could benefit methanol fuel cells: **technologyreview.com/demo**

How Has Christianity Changed over 2,000 Years?

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In the first centuries after Christ, there was no New Testament. However, books of Gospels, Acts, Epistles, and Apocalypses were widely read, and were fervently followed by groups of early Christians. But they would not be among the books that formed the New Testament.

From the many different scriptures then available, Christians held beliefs that today would be considered bizarre: that there were two, 12, or as many as 30 gods; that a malicious deity, rather than one true God, created the world; that Christ's death and resurrection had nothing to do with salvation—others insisted that Christ never really died at all.

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In these lectures you will also hear about a remarkable archaeological event: the discovery in 1945 of a treasure trove of missing Gnostic scriptures at Nag Hammadi, an Egyptian village near the city of Luxor.

Consisting of 13 leather-bound volumes unearthed in an ancient grave by Bedouin camel drivers (the full story, which you will hear, resembles the plot of a bestselling adventure novel), the Nag Hammadi Library was a watershed event in the search for lost Christianities.

About Your Professor

Dr. Bart D. Ehrman is the James A. Gray Professor and Chair of the Department of Religious Studies at The University of North Carolina at Chapel Hill. He received his Masters of Divinity and Ph.D. from Princeton Theological Seminary. He has won several teaching awards, including the Students' Undergraduate Teaching Award and the Bowman and Gordon Gray Award for Excellence in Teaching. Professor Ehrman has written or edited more than 15 books, including *The New York Times* bestseller, *Misquoting Jesus,* and *Jesus: Apocalyptic Prophet of the New Millennium*.

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8. The Coptic Gospel of Thomas
9. Thomas' Gnostic Teachings
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11. The Gospel of Peter
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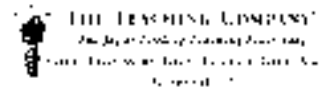

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FROM THE LABS

INFORMATION TECHNOLOGY

Better Face Recognition

A NEW ALGORITHM IMPROVES AUTOMATED RECOGNITION OF FACES IN LOW-RESOLUTION IMAGES

SOURCE: "RECOGNITION OF LOW-RESOLUTION FACES USING MULTIPLE STILL IMAGES AND MULTIPLE CAMERAS"
Pablo Hennings-Yeomans et al.
IEEE International Conference on Biometrics: Theory, Applications, and Systems, September 29–October 1, 2008, Crystal City, VA

Results: Researchers at Carnegie Mellon University and Microsoft Research have built a system that improves automated recognition of faces in low-resolution images.

Why it matters: Low-resolution images from surveillance and traffic cameras, cell-phone cameras, and webcams aren't much use for automatic face recognition, because they lack fine detail. The new system, however, can yield accurate matches from low-quality images. It could be used to search for specific faces on websites, and law-enforcement officials could use it to find suspects in surveillance videos.

Methods: Face recognition systems are usually trained on databases that include many high-resolution images of faces. That teaches them a technique called feature extraction: they learn to associate patterns of pixels with physical traits, such as a particular slant of the eyes. This training, however, doesn't equip the systems to handle low-resolution images very well. Existing algorithms can increase images' resolution—adding pixels to smooth out curves, for example. But while the results look better to human beings, the process can cause distortions that lead to errors in automated face recognition. The researchers developed algorithms that improve resolution in ways that take into account the requirements of feature extraction, increasing the accuracy of face identification.

Next steps: Face recognition systems need further improvements to correctly identify images taken from unusual angles. The researchers will also investigate other applications of image recognition—in biomedical imaging, for instance.

Electronic Eye

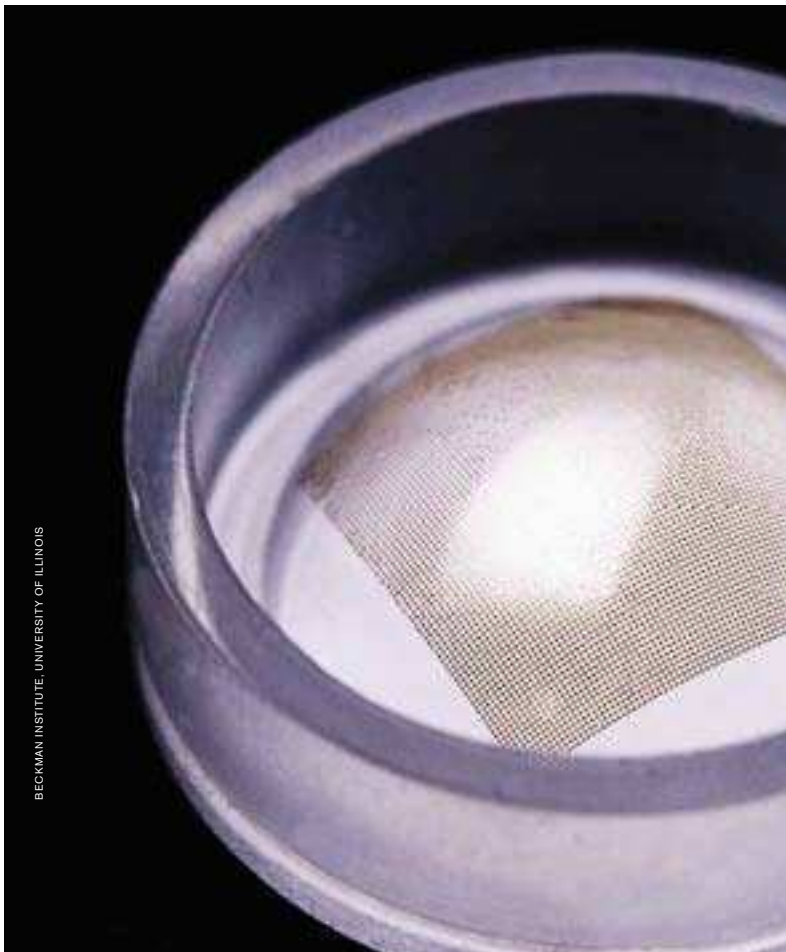
STRETCHABLE CIRCUITS ENABLE A HIGH-QUALITY SPHERICAL CAMERA

SOURCE: "A HEMISPHERICAL ELECTRONIC EYE CAMERA BASED ON COMPRESSIBLE SILICON OPTOELECTRONICS"
John Rogers et al.
Nature 454: 748–753

Results: Using a stretchable electronic circuit, researchers at the University of Illinois at Urbana-Champaign have designed a curved, 256-pixel camera sensor that produces small but high-quality images using a simple lens.

Why it matters: Unlike the human eye, with its single lens, camera lenses require multiple components to correct for distortions and aberrations that result from focusing light onto a flat surface, such as a strip of film or a conventional digital light sensor. A curved sensor doesn't require as many lens components to capture high-quality images, so lenses can be simpler and lighter.

Methods: On a silicon wafer, the researchers used conventional lithography to fabricate an array of 500-by-500-micrometer silicon light sensors connected by metal ribbons. They removed the array from its silicon substrate by means of a chemical process. Next, the research-


BECKMAN INSTITUTE, UNIVERSITY OF ILLINOIS

SILICON EYE A network of 256 tiny image sensors has been stretched over a silicone hemisphere that measures about two centimeters across.

ers used a mold to fabricate a film of flexible silicone in the shape of a bowl. Then they stretched the film flat and applied the sensor array. When they released the silicone, it returned to its bowl-like shape, curving the sensor array in the process. The metal ribbons, which are thin enough to be flexible, allow the array to bend without breaking. Finally, the researchers incorporated the array into a camera with a simple lens and electronics.

Next steps: The researchers are trying to make higher-resolution cameras that have more sensors, and they hope to use different types of curved surfaces to optimize the imaging.

MATERIALS

Cool Fuel Cells

A NEW ELECTROLYTE WORKS AT ROOM TEMPERATURE

SOURCE: "COLOSSAL IONIC CONDUCTIVITY AT INTERFACES OF EPITAXIAL ZRO_2:Y_2O_3/$SRTIO_3$ HETEROSTRUCTURES"
Jacobo Santamaria et al.
Science 321: 676–680

Results: A new electrolyte developed for use in solid-oxide fuel cells has 100 million times the ionic conductivity of conventional electrolytes at room temperature.

Why it matters: Solid-oxide fuel cells show promise for power generation because they convert a wide variety of fuels—including gasoline, hydrogen, and natural gas—into electricity more efficiently than conventional generators do. But they have been very expensive, and limited in their applications, because they require electrolytes that function only at temperatures above 600 °C. The new electrolyte works at temperatures hundreds of degrees cooler.

Methods: A solid-oxide fuel cell consists of two electrodes separated by an electrolyte. Fuel is fed to one electrode and oxygen to the other. The electrolyte transfers oxygen ions from one electrode to the other, where they combine with the fuel in a chemical reaction that releases electrons, producing an electric current. Conventional electrolytes require high temperatures because they don't conduct ions well at room temperature.

To make the new material, the researchers combined nanometer-thick layers of the electrolyte, an yttria-stabilized zirconia, with 10-nanometer-thick layers of strontium titanate. The difference between the crystal structures of these two materials leads to gaps in the electrolyte that allow oxygen ions to move freely at relatively low temperatures.

Next steps: Ionic conductivity is difficult to measure in extremely thin films like the one tested, so the improvement requires verification. What's more, creating low-temperature fuel cells will also require new electrodes that operate at low temperatures.

Metamaterial Prism

A NEW MATERIAL FOR ULTRAHIGH-RESOLUTION MICROSCOPES

SOURCE: "THREE-DIMENSIONAL OPTICAL METAMATERIAL WITH A NEGATIVE REFRACTIVE INDEX"
Xiang Zhang et al.
Nature 455: 376–379

Results: Researchers have fabricated a material that interacts with near-infrared light in a way that no naturally occurring material does. A prism made from the material has a negative refractive index: that is, it bends light in the direction opposite the one in which ordinary materials bend it.

Why it matters: The prism is the first practical device for redirecting near-infrared light in this way. Devices made from the material could be used in microscopes to produce much sharper images. They could also be used to route light on a microchip or even to render objects invisible to near-infrared wavelengths by directing light around them. Some previous negative-index materials worked only with microwaves; others, which did work with visible or infrared wavelengths, transmitted little light and were so thin that they were difficult to use. The new material is thicker and transmits more light, making it potentially more useful.

LIGHT BENDING An image produced by a scanning electron microscope shows a wedge-shaped prism. The device was carved from layers of metal and insulating material (inset) punched with rectilinear holes.

Methods: The material is made up of alternating layers of a metal, which conducts electricity, and an insulating material; both are punched with a grid of square holes. This structure gives the mate-

rial its unusual properties: it creates electrical circuits that respond to the magnetic field of light and change the way light moves through the material.

Next steps: The first applications are likely to be in high-resolution microscopy. The researchers are currently developing methods for making the material in larger quantities.

BIOMEDICINE

Better Diagnoses

DIFFERENT DISEASES SHOW SPECIFIC MICRORNA PROFILES IN THE BLOOD

SOURCE: "CHARACTERIZATION OF MICRORNAS IN SERUM: A NOVEL CLASS OF BIOMARKERS FOR DIAGNOSIS OF CANCER AND OTHER DISEASES"
Chen-Yu Zhang et al.
Cell Research, published online September 2, 2008

Results: Scientists at Nanjing University in China found that patients with lung cancer, colorectal cancer, and diabetes had characteristic patterns of microRNA circulating in their blood. Each disease was associated with a unique pattern that differed from those seen in healthy people.

Why it matters: The findings provide the basis for a type of diagnostic test that could be more accurate than those currently available. MicroRNAs are small RNA molecules that do not code for proteins but help control protein synthesis. Previous work had shown that they could play some role in cancer. But the new research is the first to find specific microRNA patterns that might be useful for diagnosis. MicroRNAs could also help doctors predict a disease's progression and evaluate a patient's responses to treatment. In addition, the study shows that microRNAs might have diagnostic potential for other diseases, such as diabetes.

Methods: Scientists used gene-sequencing technology to identify the type and levels of microRNAs in the blood serum of healthy people and people with lung cancer, colorectal cancer, and diabetes.

Next steps: The researchers are now developing the first commercial diagnostic kit based on measurement of microRNA in blood serum. They aim to release it next year. They are also trying to understand the function of microRNAs in the blood.

Cell Conversions

A REVOLUTIONARY TECHNIQUE CONVERTS ONE TYPE OF ADULT CELL INTO ANOTHER

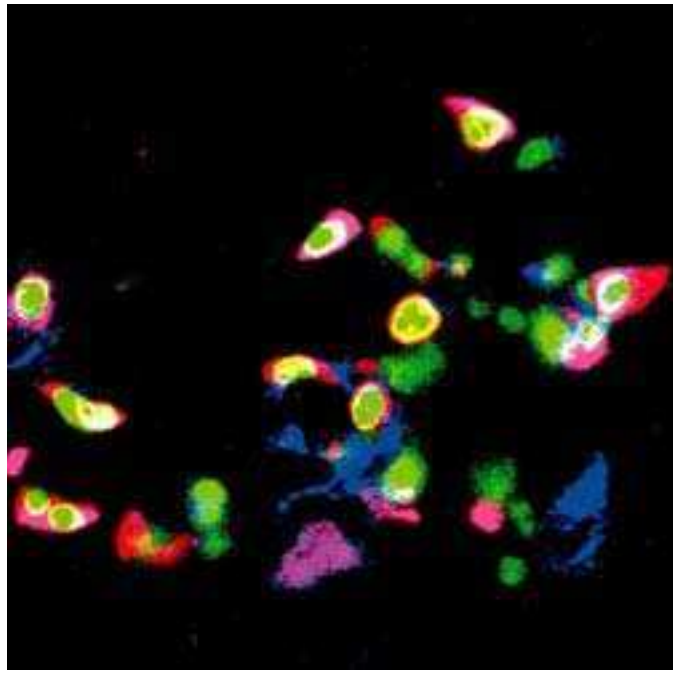
SOURCE: "IN VIVO REPROGRAMMING OF ADULT PANCREATIC EXOCRINE CELLS TO BETA-CELLS"
Douglas Melton et al.
Nature, published online August 27, 2008

Results: By activating a specific set of genes in mice, scientists at the Harvard Stem Cell Institute converted a common type of pancreatic cell into a rarer, insulin-producing one. The research is the first to show that one type of fully formed adult cell can be directly converted into another type.

Why it matters: The technique might ultimately provide a way to replace the cells lost in diabetes and other diseases, such as Parkinson's and amyotrophic lateral sclerosis (ALS, or Lou Gehrig's disease). The findings also open a new avenue of research in regenerative medicine—a field in which researchers develop therapies to repair or replace damaged cells and tissue. The technique provides an alternative to generating specific cell types from stem cells and transplanting them. Instead, scientists may be able to grow specialized cells directly from existing tissue in the body.

Methods: The researchers first identified a set of nine genes that trigger the activity of other genes in pancreatic beta cells. Then they genetically engineered mature exocrine cells, which make up about 95 percent of the pancreas, to express combinations of the nine proteins, called transcription factors, that the genes produce. Eventually, they found a combination of three that transformed the exocrine cells into insulin-producing beta cells.

Next steps: Scientists at Harvard are now trying to repeat the results with human cells. Others are trying a similar approach with different cell types, such as the motor neurons lost in ALS. TR



MAKING INSULIN Pancreatic cells that have been reprogrammed to turn into insulin-producing beta cells, the cell type lost in type 1 diabetes, produce the growth factor VEGF (blue) and insulin (red and pink). Cell nuclei are marked in green.

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The Privilege of Being Wrong

THEN AND NOW, WE FACE THE PROBLEM OF DETERMINING WHAT IS TRUE.

By MATT MAHONEY

On page 84, Simson L. Garfinkel explores Wikipedia's epistemology and discovers that, far from being the free-for-all its detractors portray it as, the world's most popular reference is decidedly rigid. In its effort to ensure accuracy, Wikipedia relies entirely on "verifiability," requiring that all factual claims include a citation to another published source (preferably online, preferably in English). As a result, Garfinkel argues, "on Wikipedia, truth is received truth: the consensus view of a subject."

There are, of course, times when the consensus view and the truth align perfectly. The problem is how to determine when this is the case. In an essay for *TR* published in April 1956, the former head of the MIT mathematics department, H. B. Phillips, described one method for doing so. Since Phillips was a mathematician, it's little wonder he appealed to the laws of probability for a solution.

Here ... is the objective criterion determining whether we know or do not know. When nearly all agree who claim to know, it is reasonable to assume that the majority view is correct. The answer may still be wrong, but if a decision is necessary the probability of error in such a case does not justify hesitation.

Although Phillips referred to his criterion as "objective," it in fact takes an agnostic attitude toward the truth. It doesn't matter whether we have fully established the truth of any given statement, because if the relevant experts are unanimous in their opinion, we can proceed as if we had. However, Phillips realized that unanimity on anything is difficult to achieve, and that we are often left to evaluate conflicting claims.

The problem is then what to do when agreement is not practically unanimous. This problem has been handled in several ways.

H. B. PHILLIPS: "It is presumptuous for any one to take his own feeling of mental certainty as final evidence that he is right."

One method is to leave the decision to a dictator. In primitive societies that was probably not a bad solution, but one that is now completely obsolete. Another method is to leave the decision to the intellectually superior. When the experts are in substantial agreement, as in science and engineering, that is certainly the correct solution. But when there is considerable difference of opinion, there is no evidence that the intellectuals supply any better answers than ordinary people. ...

These methods all have a common defect, namely, that they lead to a single solution, and when the experts do not agree any single solution is a matter of chance and therefore probably wrong. Some would say there is as much chance that such a decision would be right as wrong. But this is not correct. The choice is not one out of two, but one out of many. It is as if one should say, "I don't know how much two times three is, so I'll take a chance and say it is seven." Such guesses are almost certain to be wrong.

Phillips once again advocated a probabilistic solution, reasoning in this case that the more freedom people have to answer a question or propose a solution to a problem, the greater the chances that any one of them will have success.

If any single solution is probably wrong, the only way of increasing the chance of success is to try simultaneously a large number of solutions. The probability of including a correct solution will increase with the number of choices, and will be greatest if each individual makes his own choice. ...

When the proper course is known, action can be directed by rule or law. But when the proper course is not known, each individual should be free to go his own way to provide the greatest diversity of action and therefore the greatest probability that somebody will be right.

This diversity of thought and action is what Wikipedia has tried to harness in building its vast and ever-expanding knowledge base. By letting anyone contribute, regardless of his or her credentials, it runs the risk that absurdities, inconsistencies, and misinformation will flourish. But a free society, as Phillips argued, must allow each of its members "the privilege of being wrong." TR

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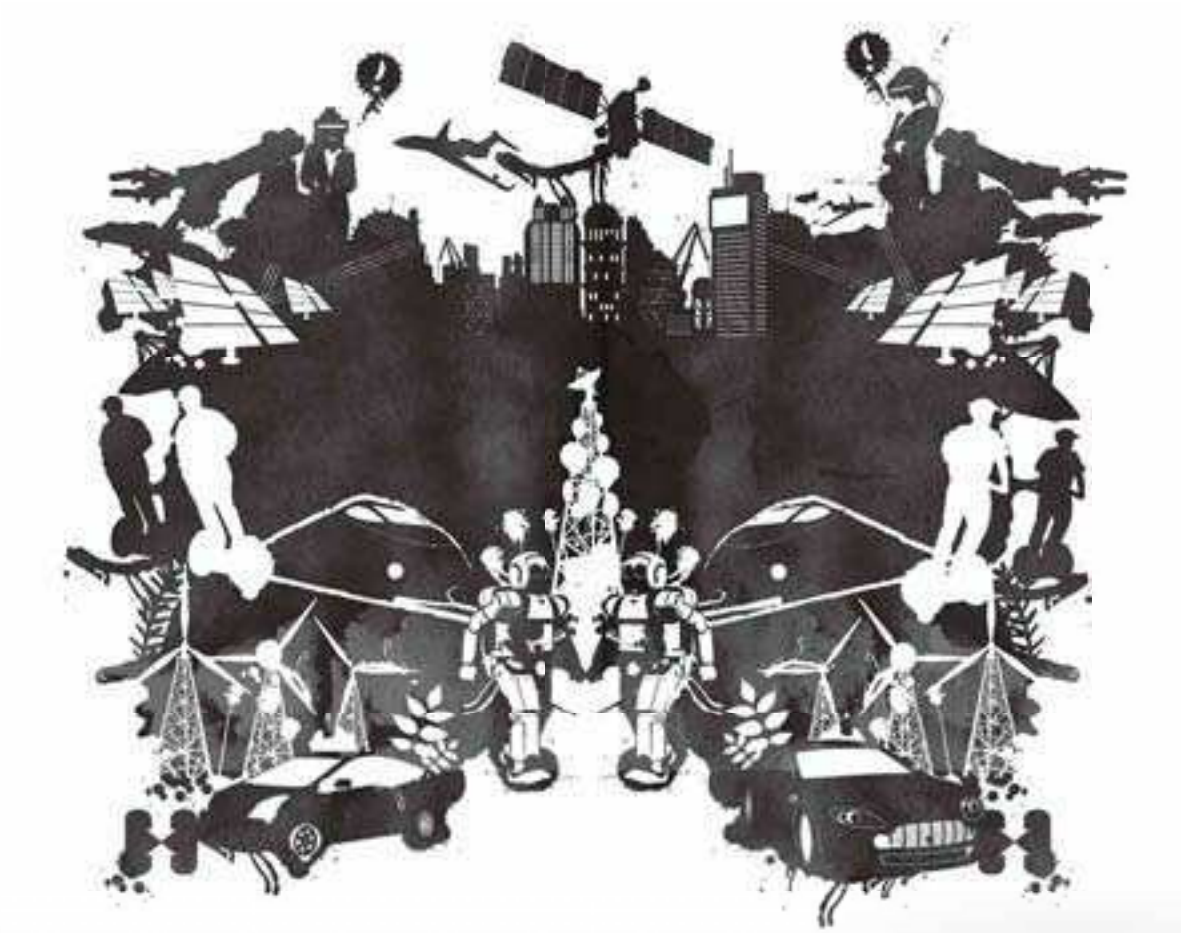

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